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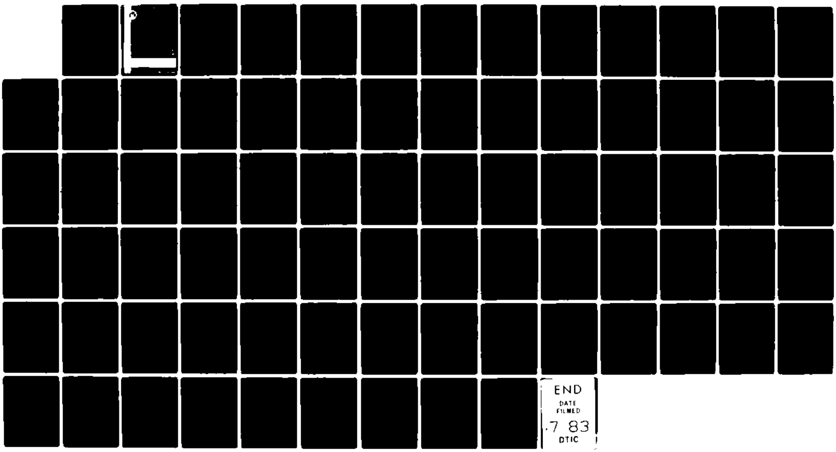

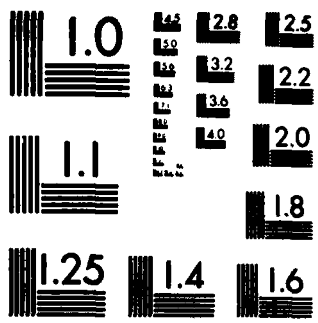
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The Instructional Support System (ISS) examined in this report is aimed at (1) increasing the utilization of existing simulators, and (2) improving the quality of training. The ISS can be strapped onto existing flight simulators without hardware or software modification. It provides an interface which instructors and students can use instead of the existing displays and controls. The ISS development had three subgoals: (1) to relieve the instructor of ancillary instructional tasks (e.g., problem setup, note taking, mission com-

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20. ABSTRACT (Continued)

munications); (2) to provide automatic ancillary instructional tasks (e.g., computer-generated briefings, automated checkrides, automated performance measurement), and (3) to provide a research tool to enable solution of unresolved design issues.

This report describes the resulting ISS and tests conducted at VF-124, Miramar NAS. An analysis of the ISS concept which emerged is presented from the viewpoints of instructional design, operational instruction, and performance measurement design.

FOREWORD

This report represents the integration of three separate studies designed to evaluate an instructional support system (ISS) for training F-14 aircraft crews. This synoptic approach had different objectives. The Allen Corporation was tasked to conduct an experimental study to assess the training effectiveness and efficiency of the system. The evaluation was done on site at Naval Air Station, Miramar under actual operating conditions. It involved assessment of Device 2F95, an F-14 Aircraft Operational Flight Trainer, with and without the assistance of the ISS. (Section IV, Instructional Designer's View)

The Canyon Research Group obtained informal interview information concerning the use of the various instructional features of the ISS from the instructor pilots of VF-124. (Section III, Instructor's View)

The Vreuls Research Corporation analyzed the data, evaluated the performance measurement capabilities of the system, and integrate the separate reports into this one. (Section V, Performance Measurement View)

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SECTION I

INTRODUCTION

Current economic considerations create pressure to minimize use of aircraft for training and to increase the utilization of existing simulators. There is also pressure to improve the quality of training which, in part, requires increased instructional capability in existing training simulators. These dual forces spawned the concept which will be examined in this report: an Instructional Support System (ISS) which can be made part of flight simulators without hardware or software modification of the original systems. The ISS provides a new student and instructor interface with the training system which may be used instead of the existing Instructor Operator Station (IOS) displays and controls; consequently, the ISS also provides a vehicle for improved instructional use of training simulators.

The ISS development has three specific goals: One is to provide Instructor Pilots with automation to relieve them of ancillary instructional tasks such as system initialization, problem setup, note taking, acting as a missing crewmember, and serving as a mission communicator. Another is to provide automated auxiliary support by incorporating support capabilities typically not found in current training simulators, such as computer-resident syllabi, computer-generated briefing, automated checkride testing, automated performance measurement and scoring, data files for establishing performance norms, automated prescriptions, student progress files, and automated debriefing. A third goal is to provide a research tool to enable the solution of unresolved design issues.

An Instructor Pilot using an F-14 OFT performs the following functions, and those which appear to be candidates for automated support are marked with an asterisk (from Semple, et al., 1977):

* Review and evaluate the trainee's progress to date.

* Decide upon training content of the simulator training exercise to be undertaken.

* Present a pre-session briefing covering the instructional objectives to be met and the mission plan to be used as the training medium.

* Interrogate the trainee on flight control, system and operational knowledges required to enable him to meaningfully benefit from the simulator exercise.

* Provide instruction in areas of trainee pre-exercise knowledge weaknesses.

• Provide over-the-shoulder instruction on cockpit controls, displays and procedures.

• Perform plane captain's role by giving hand and arm signals to trainee during performance of engine start and post-start system checks.

* Perform missing crewmember role by reading NFO checklists and monitoring trainee responses.

• Perform missing crewmember (NFO) role by participating in problem diagnosis following system failures.

* Provide training problem control in keeping with content of the Instructor's Briefing Guide.

* Adjust training problem content in keeping the trainee's observed performance.

• Communicate system, procedural and operational knowledge to the trainee.

* Provide coaching, cuing and performance feedback to the trainee.

* Insert and/or remove, or command the Training Device Operator to insert and/or remove system failures.

* Vector the trainee within a simulated warning area.

• Interrogate the trainee on system knowledge, procedures, causes and consequences of failures, flight operations, communication procedures, aircraft operations and operating limits, and NFO tasks during the training exercise.

* Take notes for performance evaluation, grading/scoring, learning problem diagnosis, and post-exercise debriefing of the trainee.

* Sample and evaluate the trainee's performance in the areas of system knowledge, normal procedures, emergency procedures, flight control, navigation, flight operations and voice communication procedures.

* Complete and annotate grade sheets.

* Perform communication functions such as: departure and approach control, tower, GCA controller, missed approach controller, Carrier Air Traffic Control Center controller, Marshall controller, Bolter controller, Landing Signal Officer controller, performance feedback, and mission instructions.

* Debrief the trainee, summarizing strengths and weaknesses as ascribing possible reasons.

* Prescribe remedial, extra and next training content.

* Perform post-exercise instructional management record keeping.

Furthermore, again in the context of the F-14 OFT, the following Training Device Operator functions appear to be candidates for partial or total automated support:

* Complete system initialization by modifying or entering data to accomplish emergency manual insertion/removal, reset, carrier site data entry, ground site data entry, and environmental data entry.

* Activate and initialize the visual system.

* Respond to Instructor and/or Trainee commands to accomplish ground power on/off, ground compressed air on/off, remove/insert (simulated) wheel chocks, remove/insert emergencies/failures, and operate slewing control to reposition the simulator.

The rationale behind the ISS concept is that through automation of functions, such as those described above, both training quality and greater utilization of existing facilities can be realized. It is assumed, for example, that reduction of instructor workload will lead to increased training quality; automation of training functions will lead to improvement through standardization and centralized control; and, improvement of simulator capability without an instructor present will lead to greater simulator utilization. It is estimated that more than 20% of Instructor Pilot's (IP) time in simulator training is devoted to ancillary tasks, and frequently the IP is occupied with simulator manipulation and cannot observe critical periods of student performance. Furthermore, in an environment such as F-14 Replacement Pilot training (where the trainees already know how to fly some aircraft), over half of simulator utilization is logged as "extra training" without an instructor present. The ISS concept is intended to provide solutions in these areas.

An ISS was designed, developed and placed in an operational environment to test the above concept. The ISS design and development was guided by a charter intended to ensure that the ISS would be responsive to both operational training needs and research needs. The charter is summarized below.

- Instructional support needs, as defined from an operational training reference point, would provide functional design guidance.

- The design was to incorporate capabilities that will enable it to be used in a research role as well as in an instructional role.

- A full support system was to be conceived with a reasonable subset of capabilities selected for trial implementation.

- Hardware and software designs were to be based on state-of-the-art technology or an extrapolation, if associated risks were modest.

- The design was to complement rather than unnecessarily duplicate instructional features of the host simulator's IOS.

- System capabilities were to maximize the likelihood of user acceptance and minimize user training requirements.

- Instructional support capabilities were to be modifiable with relative ease to keep pace with the dynamically changing flight simulator training environment.

- The design was to be generalizable to other simulator training applications.

- The resulting system design was to be transparent to the host simulator and thus not require modification to the simulator software.

The remainder of this report is devoted to a description of the resulting ISS, tests which were conducted at VF-124, NAS Miramar, and an analysis of the ISS concept which emerged. The tests which are reported here are the work of three different organizations: Allen Corporation, who performed an evaluation from the view of the instructional designer; Canyon Research Group, Incorporated, who evaluated from the viewpoint of the instructor user; and Vreuls Research Corporation, who evaluated from the viewpoint of automated performance measurement design. A fourth organization, Logicon, Incorporated, designed, developed and implemented the ISS hardware and software; their view, that of the implementer, is presented as a separate report (Kryway and Seidensticker, 1982).

SECTION II

IMPLEMENTATION FOR DEVICE 2F95

The ISS concept was implemented for Training Device 2F95 to provide a basis for test and demonstration. In addition to being a functional training aid, this ISS implementation was to be used as a performance measurement and instructional research tool for a broad range of instructional support training questions. This section provides a description of the implementation; the reader is referred to Seidensticker and Kryway (1982) for a more detailed description.

DEVICE 2F95

Device 2F95 is an Operational Flight Trainer (OFT) for the F-14A aircraft. It consists of a simulated F-14A pilot cockpit which is mounted on a hydraulically actuated motion platform that is capable of providing pitch, roll, heave and lateral displacement about the related axes. Visual scene simulation is provided by a single channel, narrow-field-of-view VITAL III-S display (Device 2B34) that provides the pilot with simulated out-of-the-cockpit night/dusk visual scenes for training land- and carrier-based takeoffs and landings.

The F-14 OFT (i.e., Device 2F95) is designed for pilot training in an independent mode, or it can be coupled with the Mission Trainer (Device 15C9A) and operated in a mission training mode. The F-14 OFT incorporates a Xerox Sigma 5 computer system and is operated principally from a remote instructor/operator station located away from, but in sight of, the simulated cockpit.

INSTRUCTOR/OPERATOR STATION FOR DEVICE 2F95

The instructor/operator station for Device 2F95 consists of an instructor/operator station, a cross-country and approach display (CCAD) and a VITAL IIIA visual system monitor.

INSTRUCTOR/OPERATOR STATION. The IOS has seven panels. Each panel has controls, indicators, or both, related to a control or indicator in the cockpit. The panels are grouped by function and arranged somewhat similarly to their related cockpit components. The controls allow the instructor to select or alter mission parameters, slew the aircraft to new coordinates or initial coordinate settings, insert malfunctions, and control emergency conditions.

The actual operation of the OFT is accomplished by programming the Alphanumeric Data Display (ADD) system and using the control panel located at the IOS. The ADD system has a total of 22 pages of programming, 9 of which deal with the parameters of the flight (i.e., carrier site, sea state, wind state, etc.). It is programmed using an input terminal which resembles a ten digit calculator. By changing the numbers on any of the parameter pages, the instructor can design an infinite number of different

training experiences which includes an option of 184 possible malfunctions. Malfunctions can be inserted independently or in combination and at any time throughout the session. The control panel contains controls and displays that allow the instructor to manage a training session. From this panel, the instructor can simulate GCA conditions, insert malfunctions into the session, control the aural cue loudness and rough air effect, and control the motion platform.

To effect a simulator lesson, a Training Device Operator (TD) programs into the ADD pages the lesson parameters which include the initial setting (i.e., on the runway, 6 miles behind the carrier, etc.), the malfunctions, wind conditions, etc. From the instructor's console, the Instructor Pilot manages the training session and monitors what the pilot is doing in the cockpit. Color-coded lights illuminate to indicate switch positions or other aircraft parameters and an array of repeater instruments provide the Instructor Pilot with information about relevant aircraft flight parameters and hence information about the performance of the student flying the simulator.

CROSS-COUNTRY AND APPROACH DISPLAY (CCAD). The CCAD is an output device that allows the instructor to monitor the flight pattern of the trainee during cross-country or approach phases of training. It consists of a 30 x 30 inch, vertically-mounted, rear-projection display screen, a random access slide projector, and related controls and indicators. On the front face of the display screen is an x-y plotter pen that plots the simulated flight on the screen.

Charts projected on the screen are based on aircraft altitude and position. The indicators include simulated position, in nautical miles east or west and north or south of either a selected navigation facility or the center of the chart, and the scale of the projected chart in nautical miles per inch.

VITAL DISPLAY. The VITAL IIIA display located at the IOS is the same as the display mounted on the OFT, but without a Fresnel lense. It provides the instructor with the same out-of-the-cockpit visual scene content as that displayed to the student. It provides a field-of-view of approximately 60 degrees. Controls located on the VITAL display allow the instructor to vary visibility and ceiling parameters of the simulated visual scene.

INSTRUCTIONAL SUPPORT SYSTEM (ISS)

The Instructional Support System (ISS) is a separate set of equipment and computers attached to Device 2F95. It controls operation of Device 2F95 by generating inputs to the host computer instead of the present IOS console. The ISS hardware and software used a transparent interface into the present trainer, requiring no changes in present trainer hardware or software. This allowed groups supporting the Sigma 5 to change their software without concern for interaction with the ISS, and, it allowed reversion to non-ISS operation at the flip of a switch.

ISS HARDWARE. A block diagram of the ISS is presented in Figure 1. The ISS hardware consists of the following equipment: The Instructor's Consoles (Primary and Secondary), Printer Plotter, Voice Generation Unit, Applications Processor and Display Processor.

Primary Instructor Console. The primary instructor's console consists of an upper and lower CRT display as shown in Figure 2. Computer input is accomplished on the lower CRT via touch panel controls. Training is controlled from the console by selecting options that are displayed on the lower CRT in "menu-like" format. Special branching routines allow the operator to branch to any desired part of the ISS program. The upper CRT is used primarily to (a) display briefing/debriefing information, (b) to show special GCA/CCA displays depicting both horizontal and vertical aircraft position, with respect to the ideal glidepath, (c) aircraft position relative to geographical positions in the form of operating areas, airways, standard instrument approaches and departures, and (d) text pertaining to subject matter in the form of aircraft procedures, pilot actions, diagnostics pertaining to procedures, and aircraft systems descriptions when called for by the operator.

Secondary Console. The secondary, or remote, instructor's console is identical to the primary console. It was located in a room adjacent to the Instructor's area of Device 2F95 and was intended to be used for training session set-up, briefing, playback, debriefing, and performance grading functions. The planning, briefing and debriefing features of the secondary console were operable simultaneously with the conduct of a trainer mission; however, use of the secondary console slowed response at the primary console.

Printer Plotter. The printer plotter functioned as a hardcopy device for instructional purposes and as a printer for maintenance and administrative purposes.

Voice Generation Unit. The voice generation unit provided a computer-generated simulation of the controlling agencies a pilot normally would communicate with during actual flight. This unit provided voice transmissions to the cockpit in the form of information, instructions and clearances With this implementation, all transmissions were made with one same-sounding voice.

Applications Processor. The applications processor consisted of computer equipment from Data General Corporation including (a) an Eclipse central processing unit with 196K, 16-bit words of main memory, (b) a 96 megabyte disk storage unit, (c) an industry standard half-inch magnetic tape unit, and (d) various interfaces with peripheral equipment and a link to the Display Processor.

The Applications Processor controlled the operation of the ISS in response to direction from operator touch panel inputs and activity on Device 2F95 using data and programs stored on the disk.

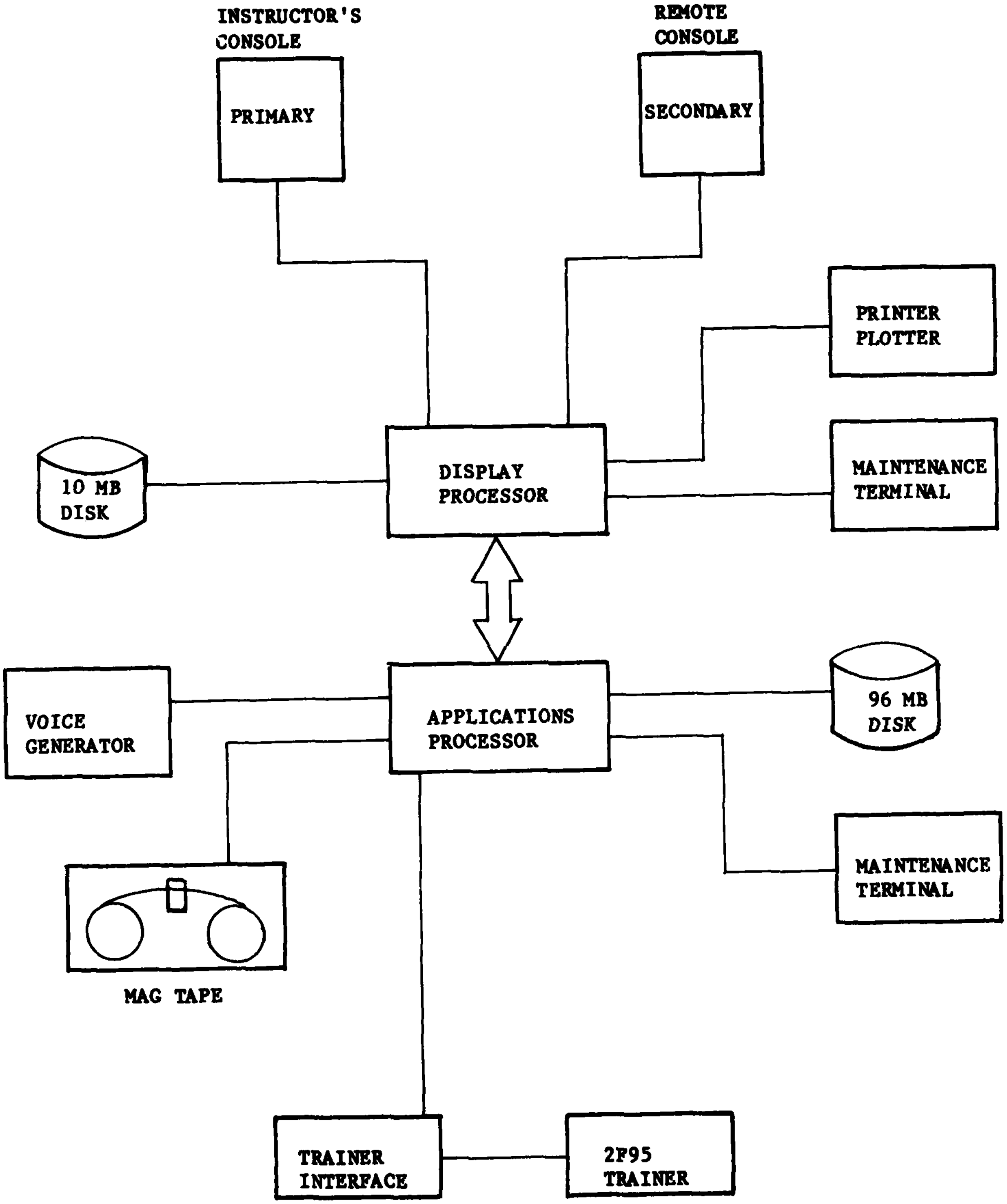

Figure 1. ISS System Block Diagram.

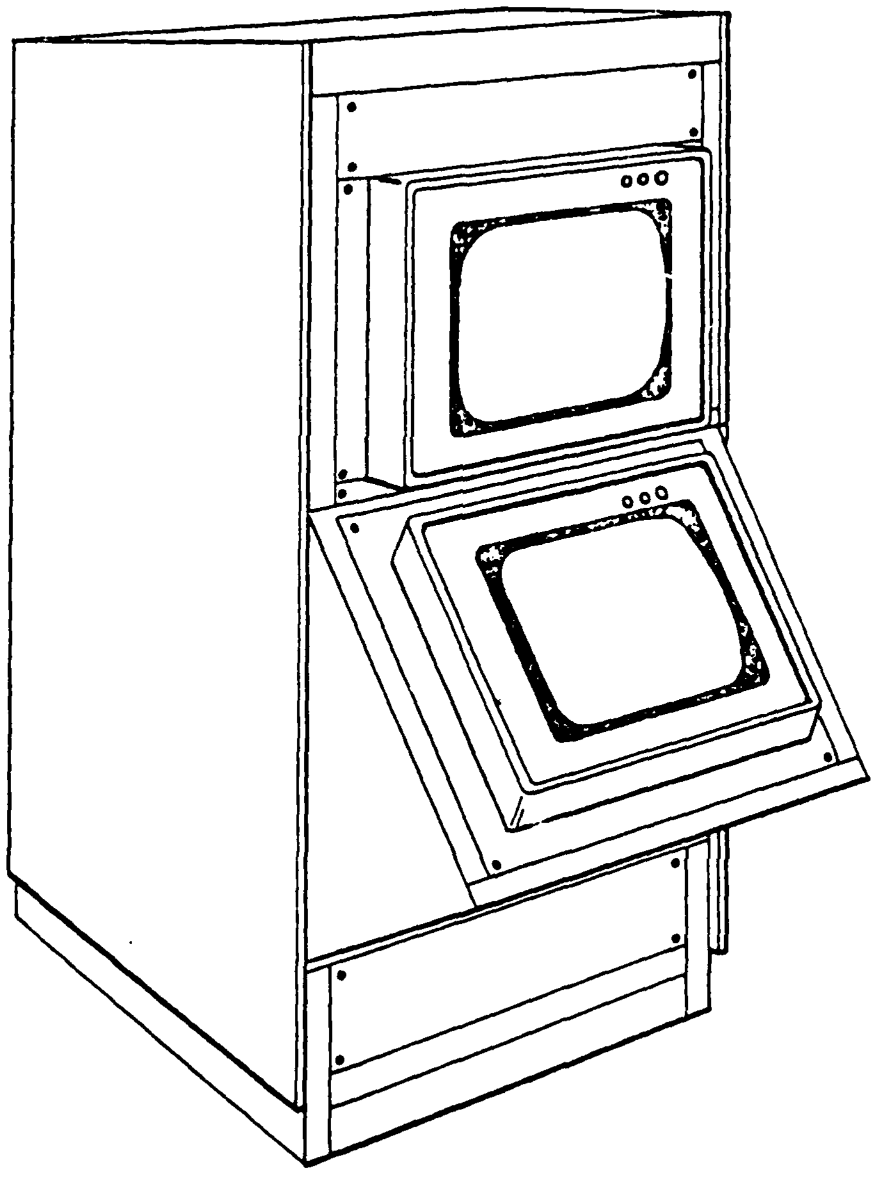

Figure 2. ISS Console.

Display Processor. The Display Processor consisted of computer equipment from Data General Corporation including (a) an Eclipse central processing unit with 128K, 16-bit words of main memory, (b) a 10 megabyte disk storage unit, and (c) a link to the Applications Processor. The Display Processor generated and controlled the images which appeared on the operator console in response to display requirements received from the Application Processor and operator commands received from the touch panels.

ISS FUNCTION AND OPERATION. The ISS was designed to provide the instructor/ operator with a choice of three modes of operation: CANNED, instructor select (ISEL), and special task training (STT).

CANNED Mode. The CANNED Mode is a completely automated mode of operation whereby training objectives in the form of task modules have been preselected and programmed to conform to a formalized training syllabus. Operating in the CANNED mode, the ISS follows a planned flight course, inserts and removes aircraft malfunctions, gives required voice communications, and calculates and assigns grades for each task objective.

ISEL Mode. ISEL Mode is a mode of operation whereby the instructor has the option, during the Training Session Set-up phase, of constructing a training session with the use of task modules to meet his own tailored training objectives.

STT Mode. The STT Mode is mode of operation designed to be used for specialized part task training of specific training objectives. It allows a training scenario to be constructed from a list of specific flight maneuvers such as GCA/CCA, ILS approaches, bolter patterns, catapult takeoff, etc. The STT Mode allows repeated practice of individual flight maneuvers through an automated re-position capability that frees the pilot from flying the simulator to the initialization point for each maneuver.

TASK MODULE CONCEPT. An analysis of the structure of FRS and probably UPT flight training reveals that the students' tasks break into functional groups with specific training objectives. A task module, in the context of ISS design, is a logically related series of external events and pilot actions that should result in the achievement of predefined training criteria. For example, a task module may be the takeoff from a particular ground or carrier base, a pre-start checklist, or a wing-sweep malfunction. Normal task modules encompass those tasks related to pre- and post-flight checkouts and checklists during flight. Flight task modules encompass those tasks related to flying skills, procedures and navigation. Malfunction task modules relate to system failures.

Tasks modules have important characteristics. They can be executed, and have well-defined beginning and ending points. They can be run in parallel, independent of each other. They form the basis of high-level simulator control, exercise definition and replay. They provide the vehicle for associated training functions, such as performance evaluation and record keeping. A more complete discussion of the task module concept may be found in Seidensticker and Meyn (1982).

PERFORMANCE MEASUREMENT AND GRADING. The ISS performance monitoring measurement and grading are discussed below.

Event Monitoring. A program dedicated to monitoring events is notified when a task module becomes active, and a file is opened which defines the specific events appropriate to that task module. Those events are then monitored and tested for specific relationships and contingencies, also defined in the task modules. Therefore, when an event occurs, alternate actions may take place depending on the circumstances present at the time. For example, a diagnostic message can be generated if the aircraft drifts off the center of the runway during takeoff.

Performance Measurement. One of the actions that may be taken as a result of an event is the calculation of measurements of flight parameters. A performance measurement program is dedicated to taking measurements for each task module that becomes active. These measurements include measurements calculated from the data obtained by sampling flight parameters 1 to 20 times per second during a prespecified mission interval, continuous measurement whenever specified limits are exceeded, or a single parameter (snapshot) sampled when a specific event occurs.

Procedure Evaluation. Performance measurement for normal and emergency procedures is accomplished differently than that for flight parameters. The event monitoring program is capable of evaluating a sequence of events such as activating switches in a particular sequence, and activating other switches in no particular sequence, but after the other switches which had to be sequenced in order. For these kinds of situations, the following measures can be calculated: critical errors, recognition reaction time, total procedure time, percent of mandatory actions taken, and percent of optional actions.

Scoring. Scores are computed when a task module is completed. A scoring template is defined along with each task module that includes all measurement definitions and scoring formulae. The template includes allowable scores (e.g. 4.0, 3.5, 3.0, 2.5) and the range of values for a measurement for each scoring category. A measure that falls within one of these ranges is assigned the corresponding score. An example of such a template, as it could be displayed to the instructor, is shown in Figure 3. Additional information on procedures monitoring and scoring in the ISS may be found in Seidensticker and Kryway (1982).

GRADING CRITERIA

SAN PEDRO DEPART FINAL GRADE = 2.7

MEASURE	NOMINAL	4.0	3.5	3.0	2.5	VALUE	GRADE	WT
DME SNAPSHOT	1	2.5	2.75	3	3.5	.79	4.0	.10
	1	0	2.51	2.76	3.01			
RADIAL DEVIATION(RMS)	280.	2	3	5	10	.69	4.0	.10
	280.	0	2.01	3.01	5.01			
ALTITUDE DEVIATION(RMS)	2000.	100.	200.	300.	500.	206.96	3.0	.10
	2000.	0	100.01	200.01	300.01			
AIRSPEED DEVIATION(RMS)	325.	10	25	50	100.	68.06	2.5	.10
	325.	0	10.01	25.01	50.01			
DME SNAPSHOT	2	1	1.5	2	3	.55	4.0	.10
	2	0	1.01	1.51	2.01			
RADIAL DEVIATION(RMS)	300.	2	3	5	10	13.96	2.0	.20
	300.	0	2.01	3.01	5.01			
ALTITUDE DEVIATION(RMS)	26000.	100.	200.	300.	500.	535.34	2.0	.20
	26000.	0	100.01	200.01	300.01			
DME SNAPSHOT	3	1	2	3	5	5.13	2.0	.10
	3	0	1.01	2.01	3.01			

Figure 3. Example Scoring Template.

SECTION III

INSTRUCTORS' VIEW

METHOD

The general methods used were interview and observation. A sample of VF-124 instructors who instructed using Device 2F95 were interviewed prior to the activation of the ISS at VF-124. Post-use interviews were conducted with a sample of Instructor Pilots after they had gained some experience with the ISS. The ISS also was observed during operation. Pre-use and post-use interviews are discussed more fully below.

PRE-USE INTERVIEWS. The purpose of the pre-use interviews was to identify any strong biases, either for or against the concepts and technologies reflected in the ISS. The interview guide shown in Appendix A was used. Each instructor who was interviewed was given a short briefing on the experimental nature of ISS and the fact that ISS was a technology demonstration and evaluation project. General features and capabilities of ISS were summarized. Interviews then were completed using the interview guide.

Two interviewers used the guide to interview 12 of approximately 20 Instructor Pilots who possibly could have used the F-14 OFT for instruction. Only four of the instructors who were interviewed ultimately used the prototype experimental ISS. It was not known at the time of the pre-use interviews which instructor would eventually use the ISS.

POST-USE INTERVIEWS. The purpose of the post-use interviews was to obtain user feedback on implementation, instructional value, ease of use and general acceptance of ISS concepts and capabilities. A single interviewer conducted the interviews using the guide presented in Appendix B. The interviewer had participated in the functional design of ISS (Semple et al., 1979) and was quite familiar with the system's capabilities.

Post-use interviews were conducted at two different time periods: September 1981 and January 1982. Four Instructor Pilots were interviewed in September, and six were interviewed in January. Of the six interviewed in January, two previously had been interviewed in September. Two additional instructors who had gained experience with ISS were not available for interview in either period.

RESULTS

PRE-USE INTERVIEWS. A majority of instructors interviewed had prior experience with computer-based systems other than aircraft avionics. Their views toward computer-based instructional assists appeared highly objective. The consensus was that the nature of the computer programs and the man-machine interface would determine the value of ISS-like systems. A general concern was expressed that computer-based instructional supports might unnecessarily limit the flexibility that all felt was needed for transition training using an operational flight trainer. More complete information on student

and system performance was seen as a benefit, as long as the information was made available to instructors in readily usable forms and formats. A majority felt that systems like ISS would not be difficult to use because of the state-of-the-art in man-computer interface design. Mixed reactions were expressed regarding whether ISS would simplify the instructor's job, and none expressed the view that ISS would result in improvements to their instructional skills. Considerable doubt was expressed regarding whether computer models of air traffic or final approach controllers would be practical. Strong objection was raised to computer-generated performance scores. Those who did not object cited potential improvements to objectivity and standardization. Most, however, objected on the following grounds. The simulator "flies" differently from the aircraft, and therefore, simulator performance scores would be invalid. The same instructors questioned the "flight" training value of Device 2F95, particularly with respect to precise flight path control. Computer-based scoring is too rigid. Much of flying is "subjective" and focuses on decision making, which they felt was not amenable to automated scoring. Several expressing these views also indicated that they might be less apprehensive after using computer-generated performance scores. A majority also expressed a pre-use view that instructor station information displays should include cockpit instrument forms, at least for flight control, propulsion system and any trend information. A "wait and see" attitude characterized responses responses to the acceptability of the touch panel information entry characteristic of ISS.

POST-USE INTERVIEWS. The following text presents instructor opinions and viewpoints to ISS topics not directly addressed in Chapter IV.

Overall Impressions. Not all of the instructors who used the experimental prototype ISS had the opportunity to gain desired levels of experience and proficiency with the system. Additionally, not all received adequate instruction on the system's purposes, capabilities, options and limits. Their viewpoints and opinions must be interpreted in this general context.

A majority of instructors who used ISS viewed most of the instructional support and control-display concepts embodied in the system as sound. Exceptions are noted below. Also, a majority expressed the opinion that ISS technologies present a solid basis around which to build future instructor/operator stations and support systems for simulator training. Computer graphics displays were well received because they provided pictorial representations of flight. Consolidations of control options and display content into highly focused, easily scanned areas also were commented upon favorably.

On the negative side, perceived reductions in instructor options and instructional flexibility were viewed with disfavor. Automated malfunction insertion and removal, together with automated performance scoring, were found to be at the forefront of this objection. Additionally, several Instructor Pilots expressed the view that simply adding ISS-like capabilities to existing instructor/operator stations likely would not be productive. This view reflected a lack of understanding on the part of

some that the experimental prototype ISS was intended largely for technology exploration and refinement, rather than an adjunct to existing simulator consoles.

Use of Existing IOS Displays. The experimental prototype ISS station was not intended to fully replace the existing instructor/operator station. Rather, it was intended and designed to replace some functions, add functional capabilities, and only complement others. For example, the ISS design did not attempt to duplicate or displace flight control or propulsion information displays on the existing console. Configuration information, including gear, flap and wing position, were displayed on ISS. All instructors interviewed indicated that they did refer to flight, configuration and propulsion information displays on the existing console. Several commented that they referred to the existing console much less frequently then they thought they would. Only one interviewee expressed the opinion that the ISS provided no information which was not directly available or estimable from the existing instructor/operator console. All others felt that the ISS provided additional, useful information.

Display Viewing Comfort. All instructors who were interviewed indicated that neither the graphics nor alphanumeric displays produced any noticeable visual fatigue. Additionally, all displayed information was easily readable. Glare also was not a problem.

Touch Panel Control Medium. Instructor inputs to ISS were made using a CRT touch panel. Instructors found this control medium quite acceptable, but did not strongly favor it over rotary switches, pushbuttons, keyboards or other control devices. A majority commented that controls were much more centralized and easier to reach using the touch panel.

The ISS touch panel mechanization resulted in several instructor complaints. One involved registration. Several touches on or near the target often were required to achieve control activation. When a control input called for a new information display, an additional problem was that several seconds could elapse between the request for the display and the presentation of the display. If the control target was again touched in this lag period, a different and undesired input to ISS could result. Both of these problems can be overcome through different mechanization.

One aspect of making the touch panel control input approach acceptable appears to be providing all immediately necessary control capabilities on each control page that is displayed. This is needed to avoid having to page through numerous displays to get the desired control input capability. ISS appeared to have achieved this goal, which is highly desirable.

Automated Checklists. The automated checklist displays presented procedural sequences that student pilots should perform, for example, during engine start. Clock times at which each procedure was performed were displayed beside a text readout of each procedural step. This allowed the instructor to monitor the sequence in which procedures actually were accomplished. Additionally, certain improper procedures were displayed as "diagnostic" information.

This design characteristic was one of the most well accepted by the instructors who were interviewed. The information that was displayed was viewed as valuable as was well in addition to similar information available through the existing instructor/operator station. Clock times, per se, were not believed to be of value. Rather, the importance of this indication was felt to lie in providing the instructor with a visual indication of procedural sequences. The potential value of using hardcopy printouts of automated checklist information for debriefing remains unknown.

Aircraft Systems Information Callups. The ISS contained several aircraft system information files that instructors could call up for display via the runtime menu. Information displayed to the instructors was both graphic and textual, and was taken directly from relevant pages of the F-14 NATOPS manual.

Three instructors used the system information callups. All three found the information of value for instruction. The level of detail involved exceeds typical human long term memory characteristics. Also, a copy of the needed NATOPS manual pages frequently is not available at the training device.

Based upon the positive instructor response to the memory aid value of the systems information callups, it appears desirable to consider similar information callups in future instructor/operator station applications. If provisions for similar information display are made in future devices, provisions for easy modification of information content also must be made. This follows since, for example, the content of NATOPS manuals changes quite often, and information stored in an instructional support system could become quickly outdated.

Digital Readouts. The ISS graphics display presented digital readouts of selected information elements such as heading, airspeed and communication/navigation channels selected by the simulator pilot. Practically none of the instructors interviewed recalled having seen or used the digital readouts. Practically all indicated a preference for cockpit-type instruments at the instructor/operator station, probably since they are most familiar with these display types. Additionally, almost all expressed concern about using digital readouts to assess trend information. Several commented, however, that the concept appeared interesting from the standpoint of concentrating a number of information elements into a relatively compact area. They noted that this would reduce scanning requirements.

From an historical standpoint, displaying the communication and navigation channels selected by the simulator pilot was done to solve particular problems. The existing OFT instructor/operator console does not display these information elements. This has resulted in a number of cases where the instructor and student were not coordinated in navigation and communication tasks. This detracted from available simulator training time and, possibly, simulator training value.

Programmed Malfunctions. ISS had the capability in both the CANNED and ISEL modes to automatically insert and remove malfunctions. About midway through

the evaluation, the ISEL mode was modified to enable manual malfunction insertion and removal.

None of the instructors reacted favorably to automatic malfunction insertion or removal. The following reasons were given. Programmed malfunctions were too rigid and the selection and timing of malfunctions were not under instructor control. If a student pilot had not effectively coped with an ongoing malfunction, burdening him with a second malfunction, somewhat concurrently, was felt to interfere with instructor intervention. Some malfunctions were automatically removed before they were handled effectively. The fact that they were not handled effectively could have caused subsequent system failures. Clearly, this would pose an undesirable training event with potentiallly undesirable operational consequences.

The need to allow instructors to arbitrarily change their minds on which malfunctions should be inserted was not well justified by the instructors, aside from the fact that the existing console enables them to do so. The other points are valid. It should be noted, however, that the ISS concept allowed for the occurrence of subsequent, related malfunctions if the one inserted was not effectively handled.

The midway change to the ISEL mode allowed instructor selection of malfunctions and control over their insertion and removal. The modification was well received the instructors who used it. Similar approaches on other training simulators have been well received by instructors (Semple, et al., 1981). In these systems, malfunctions to be used during a training session are selected from an electronically generated shopping list. Those selected then can be displayed during training, and easily inserted and removed at the instructor's discretion.

Automated Performance Scoring. ISS incorporated automated performance measurement capabilities for developing task module performance scores. Scoring was possible for both procedural and flight modules. Scores were generated using best estimate scoring algorithms which had not been subjected to empirical research and development. The scores that were produced were normalized to a scale of one through four, corresponding with the grading scale used by VF-124. In the initial ISS configuration, task module performance scores were displayed to the instructor only at the conclusion of training, for use during debriefing. At that time instructors also could call up the performance measurement details that went into the makeup of any score. Approximately midway through the evaluation, ISS was modified to also display performance scores at the conclusion of each task module (e.g. during training). During the debriefing mode, instructors could change any performance score through the ISS console.

Several of the instructors interviewed either did not observe the ISS-generated performance scores or felt they had too little experience with them to comment validly. Those who had some experience with the scores commented that the scores did not appear valid. This was to be expected since the scoring algorithms being used had not been tested or refined. A majority of those who viewed the s ores expressed doubts that computer

scoring was applicable to piloting skills. Others felt the concept was too rigid and would preclude instructor inputs. Anticipation of the latter concern was one reason for allowing instructors to change computer generated scores in the ISS debriefing mode. None, however, used ISS in the debriefing mode and so they were unaware of this capability. A minority of instructors interviewed indicated a willingness to try out more fully developed performance scores before rendering a final opinion.

Hardcopy Printouts. ISS was capable of providing hardcopy printouts of various alphanumeric and graphic information displayed at the ISS instructor's console. The hardcopy capability was not used by any of the instructors interviewed. One, however, had used hardcopy printouts of GCA approach profile graphics from a training simulator he had used on a prior assignment. He indicated that the graphics printouts were useful during debriefing. Similar uses of graphics hardcopy printouts have been reported by Semple, Cotton and Sullivan (1981). Neither the present study nor prior studies, however, have been able to address the value of other types of hardcopy printouts, such as performance scores or checklist procedural details, for debriefing. The value of hardcopy printouts as debriefing aids requires additional investigation.

SECTION IV

INSTRUCTIONAL DESIGNERS VIEW

PURPOSE

The purpose of the investigation described in this section was to assess the contribution of the ISS to the training and operational efficiency of Device 2F95. This assessment took the form of an experimental comparison of the effectiveness and efficiency of the training provided by Device 2F95 with and without the assistance of the ISS. More specifically, data were collected for the following measurement categories: training effectiveness, training efficiency, standardization of training, effectiveness and utilization of special instructional feature, and general measure of ISS and Device 2F95 IOS operation and performance.

METHOD

SUBJECTS. The personnel who served as subjects for the study were student pilots undergoing training at Fleet Replacement Squadron (FRS) VF-124 located at NAS Miramar, California. Student pilots were categorized according to their previous flying experience. Category I refers to pilots who have only completed Undergraduate Jet Pilot Training (UJPT), or pilots who, after completing UJPT, served as UJPT instructor pilots before being assigned to the FRS. Category II refers to pilots who normally have between 600-1000 hours of total flight time and that have fleet fighter experience in an aircraft other than the F-14. Category III refers to pilots who have operational experience in the F-14.

Overall, thirty-three student pilots participated in the study. Twenty students from classes 8101, 8102 and 8103 took part in the CQ portion of training. Twelve of these students were Category I pilots, six were Category II pilots and two were Category III pilots. Two of the Category I pilots repeated CQ training and were included in the study both times because it was felt that the previous CQ training would not affect the measures being collected. Thus, data were collected for the equivalent of 22 students undergoing CQ training.

Thirteen students from classes 8107, 8108 and 8201 participated in the FAM training portion of the study. Twelve of these students were Category I pilots and one was a Category III pilot.

INSTRUCTORS. Seventeen Instructor Pilots with different levels of experience participated in the study and were those normally assigned by VF-124. A brief orientation course on how to operate the ISS and on the purpose of the study, was provided to some VF-124 personnel before the study began. Several training sessions on how to operate the ISS also were scheduled prior to the study. However, many of the instructors who participated in the study were neither available for the orientation nor the training.

Instructor training on how to operate the ISS typically was given "on-the-job" by Logicon personnel. It normally began the first time an

instructor arrived to conduct a training event that was scheduled to be given with the assistance of the ISS. Students who participated in CQ training, and underwent ISS training, were trained to use the ISS in a similar manner. (All of the ISS controlled CQ trainer events were self-instructed).

STUDY DESIGN. The study was designed to assess the contribution of the ISS to the effectiveness and efficiency of Device 2F95 training. This involved having two separate groups of students undergo training; a control group which received their training with the standard IOS in operation and an experimental group which received their training with the assistance of the ISS. Experimental and control groups were formed separately for both FAM training and CQ training for a total of four groups. Students were assigned to experimental and control groups in a manner that matched, as nearly as possible, the amount and type of previous flying experience.

Category I pilots who had previous UJPT instructor experience were matched on the basis of type of IP experience (T-2C or TA-4J), whereas students were matched on the basis of overall UJPT grades. Category II pilots were matched on the basis of previous type of fighter experience. Students were followed through their training one class at a time and therefore were matched within their own class. Overall, eleven students each were assigned to the control and experimental groups for CQ training. For familiarization (FAM) training, seven students were assigned to the control group and six students to the experimental group.

Data were collected on experimental- and control-group students undergoing training on Device 2F95 for the Familiarization events: FPT 010, FAPT 020, FAPT 030 and FAPT 040. Likewise, data were collected for Carrier Qualification events: CQPT 010, CQPT 020 and CQPT 030. In addition, data were collected for simulator qualification events FAPT 050 and CPT 040. However, these two events were always trained with the IOS regardless of the previous group assignment.

DATA COLLECTION PROCEDURES. Students were scheduled for their simulator training according to the syllabus requirements of VF-124. All students received the same training for each particular stage of training. The only difference between the training received by control and experimental students was the console (IOS or ISS) from which training was controlled.

Students were monitored and data were collected during briefing and debriefing periods as well as during actual trainer activities. When the student/instructor arrived at the trainer area for their first FAM or CQ training event, they were provided ISS training, as required, and informed of the purpose of the study. It was emphasized that the intent of the study was not to evaluate either student or instructor performance per se, but, instead, to evaluate the operational aspects of the instructor's station.

Instructors and students were informed that data collection and observation would be discontinued at their request if they thought it would

interfere with training. This option was exercised only once when the data collector was asked not to attend a debriefing, or copy the grades, of a student who received a "down" on a CQ trainer event (CQPT 00).

Multiple measures were collected on the way in which training was conducted for IOS- and ISS-controlled training. They included:

- Amount of time spent briefing the event to be trained.
- Amount of time taken to set-up or initialize the trainer.
- Amount of time simulator was actually used for training.
- Number and type of syllabus events completed per training event. (CQ only)
- Number and type of special instructional features used for briefing, actual training, and debriefing.
- Number of times IOS/ISS had to be re-initialized due to IOS/ISS malfunction.
- Number of times IOS/ISS training terminated due to IOS/ISS malfunction.
- Number and type of aircraft malfunctions inserted.
- Number and type of errors made by IPs and TDs in operating instructor's console.
- The amount of time spent debriefing.
- ISS-generated grades of student performance.
- IP grades of student performance.

These measures, except for grades, were collected on data collection forms developed especially for the evaluation. They were supplemented by the observations and recorded comments of the data collector. Instructor grades were collected by copying the instructor's grade sheet, including instructor comments. ISS-generated grades were either copied directly from the ISS display or accessed as hardcopy printout.

RESULTS

This section presents the results of the comparison of Device 2F95 training conducted with and without the assistance of the ISS. For purposes of comparison, data were collected for a total of 50 trainer events for students trained with the ISS and 54 trainer events for students trained with the standard IOS. In addition, data were collected for 29 FAPT 050 and CQPT 040 events all of which were trained with the IOS. A summary of

the number and type of trainer events for which data were collected is provided in Table 1. The number of events shown in Table 1 provide the basis for all subsequent data collections.

The results of the evaluation, which are discussed below, were arranged according to the following categories of measurement: training effectiveness, training efficiency, standardization of training, effectiveness and utilization of special instructional features, and general measures of ISS/IOS performance and operation.

As indicated previously, no statistical analyses were performed on the collected data. Therefore, any reported differences in the data does not necessarily imply either statistical significance or reliability.

TRAINING EFFECTIVENESS

The overall effectiveness of ISS training was assessed by comparing the performance of students trained with the ISS with the performance of students trained with the IOS. Within the context of this study the only available measures of student performance were instructor grades for simulator training. The ISS was not ready to train all of the FAM events or all of the CQ events. Consequently, FAM and CQ training for students assigned to the experimental group consisted of a mix of events, some of which were trained with ISS and some of which were trained with the IOS. Therefore, it would have been impossible to establish a cause-effect relationship between mode of simulator training and subsequent flight grades. In addition, CQ events CQPT 010, CQPT 020 and CQPT 030, were student-instructed events, hence there were no instructor grades available for these events.

Table 2 shows average instructor grades for FAM events FAPT 10, FAPT 020, FAPT 030 and FAPT 040 for students trained with the ISS and students trained with the IOS. As shown, there was little difference in instructor grades for individual FAM events for students trained with the ISS or the IOS. The overall average grade received for FAM training event was 3.13 for both IOS and ISS trained students.

Table 2 also shows grades for events FAPT 050 and CQPT 040. Both of these events were trained using the IOS. However, they were the final simulator training events that just preceded the first aircraft flight for their respective stages of training. As such they provided a possible measure of the effectiveness of the previous simulator training events for that stage. Average grades for the two groups of students, however, were essentially identical. The average FAPT 050 grade was 3.14 for IOS-trained students and 3.15 for ISS-trained students. Similarly, the average CQPT 040 grades were 3.06 and 3.04, respectively, for IOS and ISS trained students.

TABLE 1. NUMBER OF TRAINING EVENTS FOR WHICH DATA COLLECTION WAS COMPLETED

IOS-TRAINED (CONTROL GROUP)

EVENT	CAT I	CAT II & III	TOTAL
FAPT 010	5	1	6
FAPT 020	6	1	7
FAPT 030	6	1	7
FAPT 040	5	1	6
TOTAL	22	4	26
CQPT 010	3	3	6
CQPT 020	7	4	11
CQPT 030	7	4	11
TOTAL	17	11	28
FAPT 050	8	1	9
CQPT	11	9	20

ISS-TRAINED (EXPERIMENTAL GROUP)

EVENT	CAT I	CAT II & III	TOTAL
FAPT 010	4	0	4
FAPT 020	6	0	6
FAPT 030	6	0	6
FAPT 040	6	0	6
TOTAL	22	0	22
CAPT 010	4	2	6
CAPT 020	7	4	11
CAPT 030	7	4	11
TOTAL	18	10	28

TABLE 2. INSTRUCTOR GRADES OF STUDENT PERFORMANCE

IOS-TRAINED (CONTROL GROUP)

EVENT	CAT I	CAT II & III	TOTAL
FAPT 010	3.13	3.25	3.15
FAPT 020	3.14	3.07	3.13
FAPT 030	3.14	3.13	3.14
FAPT 040	3.10	3.06	3.09
AVERAGE	3.13	3.13	3.13
FAPT 050	3.15	3.13	3.14
CQPT 040	3.05	3.07	3.06

ISS-TRAINED (EXPERIMENTAL GROUP)

EVENT	CAT I	CAT II & III	TOTAL
FAPT 010	3.23	-	3.23
FAPT 020	3.09	-	3.09
FAPT 030	3.11	-	3.11
FAPT 040	3.10	-	3.10
AVERAGE	3.13		3.13
FAPT 050*	3.15	-	3.15
CQPT 040*	3.00	3.15	3.04

*Trained with the IOS

TRAINING EFFICIENCY

Training efficiency refers to the amount of time required to conduct training activities or activities that are required to support training. Several measures of efficiency were collected. They included: (a) the amount of time required to set up (prepare) the training device for a particular event, (b) the amount of time required to reposition the trainer either to repeat a training activity or to initiate another training activity, (c) the actual amount of time the trainer was used to conduct training, and (d) the number of training activities or events completed per training session.

TRAINER SET-UP TIMES. The amount of time required to set-up Device 2F95 for a training event is shown in Table 3. Set-up times for ISS training were uniformly longer than set-up times for IOS training. The average trainer set-up time for FAM events was 1.72 minutes for IOS training and 2.11 minutes for ISS training. Larger differences were recorded for CQ training where set-up times averaged 1.30 and 3.96 minutes, respectively, for IOS and ISS training.

TABLE 3. TRAINER SET-UP TIME IN MINUTES

EVENT	IOS TRAINING	ISS TRAINING
FAPT 010	1.87	2.75
FAPT 020	1.86	2.58
FAPT 030	1.57	1.83
FAPT 040	1.67	1.50
AVERAGE*	1.72	2.11
CQPT 010	1.50	5.80
CQPT 020	1.27	3.36
CQPT 030	1.21	3.55
AVERAGE	1.30	3.96

*Note that numbers of training events, as presented in Table 1, were used in the calulation of averages.

The longer set-up times for ISS training appeared to be due to two factors. First, the ISS must be initialized for each student, whereas the IOS does not require reinitialization if successive students are being trained on the same event. Second, when the ISS was operated in the STT mode, as it was for CQ training, the student builds his own training scenario by selecting from a menu of training modules for the stage of training he was interested in. This required some planning on the part of the instructor or student inasmuch as the entire training session was planned and programmed before the session began. The ISS then automatically sequenced the student through the selected set of training activties. Students using

the IOS tended to plan only one event at a time which initially required little or no set up time. Then they either repeated the same event over or they had the TD reposition them for another event.

Set-up times for the ISS differed depending on the mode in which it was operated. The STT mode requires the most set-up time, the CANNED mode the least time, and the ISEL mode an intermediate amount of set-up time. This difference is reflected in the data set-up times for ISS training; set-up times were nearly twice as long for CQ events, where the STT mode was used, as they were for FAM events where the CANNED and ISEL modes were used. There also was some evidence that both students and instructors learned to accommodate to the different requirements for ISS training inasmuch as ISS set-up times decreased over successive ISS training sessions.

RESET/REPOSITION TIMES. There were no differences in the IOS and the ISS in the amount of time required to reset the trainer to repeat a given training activity or to reposition it for another activity. However, reset and repositon were accomplished automatically by the ISS, but they were normally performed manually by the TD at the instructor/operator station when the IOS was used.

ACTUAL TRAINING TIME AND TRAINING ACTIVITIES. The amount of actual training time, exclusive of briefing and set-up times, was calculated for IOS and ISS training. However, training sessions were scheduled for a fixed amount of time and therefore were influenced by the amount of time spent briefing and setting-up the trainer. For FAM training, where differences in briefing and set-up times were relatively small, the average amount of actual training received was essentially the same for IOS (87.1 minutes) and ISS (86.2 minutes) training events. For CQ training, where there was a larger difference in the amount of time spent for briefing and set-up, the average amount of actual training was 49.7 minutes when the IOS was used compared to 34.0 minutes when the ISS was used. The average number of training activities (e.g., ILS approach) completed per CQ training session was 11.5 for IOS training and 13 for ISS training. However, these numbers are not directly comparable because the specific manner in which events were trained varied between IOS and ISS controlled training. For example, the distance from the carrier to the initiation point of an ILS approach varied between trials and between students when the IOS was used, but was always the same when the ISS was used.

STANDARDIZATION OF TRAINING

SYLLABUS DEVIATIONS. A potential advantage of an automated instruction support station is increased standardization of training. In this reference standardization was measured by counting the number of syllabus deviations that occurred for each training event. A syllabus deviation was defined as an omission of a training activity called for by the Trainer Briefing Guide (these activities are listed in Appendix A). Syllabus deviations due to equipment malfunction were not counted nor were events that were added to the syllabus.

Table 4 shows the average number of syllabus deviations recorded for each FAM and CQ training event. Overall, the average number of syllabus deviations per training session was slightly higher for FAM training when the IOS was used (2.42) than when the ISS was used (2.09). On the other hand, the number of syllabus deviations was slightly lower for CQ training when the IOS was used (1.78) than when the ISS was used (2.00). The difference between FAM and CQ training probably were due to the mode in which the ISS was operated. That is, the ISS was operated in the CANNED and ISEL modes for FAM training which provided less flexibility in selecting training activities. However, the ISS was operated in the STT Mode for CQ training. This mode provided more flexibility in selecting syllabus events and hence may have resulted in more syllabus deviations.

The most frequent syllabus deviations and their relative frequency of occurrence are shown in Table 5 for FAM training and in Table 6 for CQ training.

AUTOMATED PERFORMANCE MEASUREMENT AND GRADING. The automated performance measurement and grading capability of the ISS affords an opportunity to increase the standardization of instructor-assigned grades of student performance. However, this feature of the ISS was the subject of a separate contract and will not be discussed here except with reference to its potential contribution as a special instructional feature.

EFFECTIVENESS AND UTILIZATION OF ISS INSTRUCTION FEATURES

An attempt was made to assess the effectiveness and utilizaton of ISS instructional features that are not currently provided by the IOS. Some of these functions are especially well suited to assist the student and instructor during briefing and debriefing activities. Other ISS functions are not specific to a particular training activity and are therefore addressed simply as special instructional features.

AUTOMATED BRIEFING. An important aspect of training involves adequately preparing the student for the training he is to receive. This may involve ensuring that he has sufficient knowledge to benefit from training, explaining the content or course of training, providing special instructions, highlighting things to look for, reviewing procedures, etc. Special features of the ISS would allow a student to brief himself or they could be used as an aid by the instructor to conduct the briefing.

The original training concept was to provide a remote (secondary) ISS instructor's console that could be used off-line by the student or instructor prior to the scheduled simulator training event. However, the remote console was not operating during the data collection period. Therefore, the automated briefing function of the ISS had to be utilized from the primary instructor's console that was being used to conduct training. In most cases the trainers were scheduled such that there was no free time available between successive trainer events. Consequently, instructors and students rarely had an opportunity to use the ISS before their scheduled training session. Students and instructors usually completed their

TABLE 4. SYLLABUS DEVIATIONS PER TRAINING SESSION

IOS-TRAINING (CONTROL GROUP)

EVENT	MEAN NUMBER OF DEVIATIONS
FAPT 010	4.50
FAPT 020	1.14
FAPT 030	2.29
FAPT 040	2.00
AVERAGE*	2.42
CAPT 010	1.83
CAPT 020	1.55
CAPT 030	2.00
AVERAGE	1.78

ISS-TRAINING (EXPERIMENTAL GROUP)

EVENT	MEAN NUMBER OF DEVIATIONS
FAPT 010	4.00
FAPT 020	2.33
FAPT 030	1.00
FAPT 040	1.67
AVERAGE	2.09
CAPT 010	1.83
CAPT 020	1.91
CAPT 030	2.18
AVERAGE	2.00

*Note that numbers of training events, as presented in Table 1, were used in the calculation of averages.

TABLE 5. MOST FREQUENT SYLLABUS DEVIATIONS FOR FAM TRAINING

MODE OF TRAINING	EVENT	SYLLABUS DEVIATION/OMISSION	PERCENTAGE OF TOTAL DEVIATIONS
IOS	FAPT 010	1. CIRCUIT BREAKER RE #1 FAIL	17.9%
		2. SPOILER LIGHT	10.7%
		3. MAC TRIM ADVISORY LIGHT	10.7%
ISS	FAPT 010	1. CIRCUIT BREAKER RE #1 FAIL	18.9%
		2. RIGHT ENGINE FUEL PRESSURE FAIL	12.5%
		3. EMERGENCY GENERATOR FAIL	12.5%
		4. SINGLE-ENGINE APPROACH	12.5%
IOS	FAPT 020	1. NO CANOPY LIGHT	25%
		2. NO WAVE-OFF ON FIRST SINGLE-ENGINE APPROACH	25%
ISS	FAPT 020	1. NO WILD CARD MALFUNCTION	31.3%
		2. REMOVED UNSCHEDULED WING-SWEEP MALFUNCTION BEFORE INSERTING SPOILER LIGHT	25%
IOS	FAPT 030	1. NO WILD CARD MALFUNCTION	31.3%
		2. RIGHT AICS FAILURE AND RIGHT RAMP LIGHT GIVEN SEPARATELY INSTEAD OF TOGETHER	31.3%
		3. LEFT EXHAUST NOZZLE FAILURE AND OVERSPEED VALVE LIGHT GIVEN SEPARATELY INSTEAD OF TOGETHE	12.5%
		4. BLOWN TIRE	12.5%
ISS	FAPT 030	1. NO WILD CARD MALFUNCTION	37.5%
		2. BLOWN TIRE	37.5%
IOS	FAPT 040	1. BLOWN TIRE ON TAKEOFF	25%
		2. CANOPY LIGHT	16.7%
		3. AIRSPEED INDICATOR FAIL	16.7%
ISS	FAPT 040	1. NO WILD CARD MALFUNCTION	37.5%
		2. FLAP MALFUNCTION	25%

TABLE 6. MOST FREQUENT SYLLABUS DEVIATIONS FOR CQ TRAINING

MODE OF TRAINING	EVENT	SYLLABUS DEVIATION/OMISSION	PERCENTAGE OF TOTAL DEVIATIONS
IOS	CQPT 010	1. NO BOX PATTERN	45.5%
		2. NO MIRAMAR LANDINGS	45.5%
ISS	CQPT 010	1. NO BOX PATTERN	36.4%
		2. NO MIRAMAR LANDINGS	36.4%
		3. NO TAKEOFF	27.3%
IOS	CQPT 020	1. NO MARSHAL PATTERN	41.2%
		2. NO BOLTER PATTERN	29.4%
		3. NO CV 1 APPROACH	23.5%
ISS	CQPT 020	1. NO MARSHAL PATTERN	52.4%
		2. NO CV 1 APPROACH	19.0%
IOS	CQPT 030	1. NO BINGO PROFILE	45.5%
		2. NO CV 3 APPROACH	27.3%
		3. NO OVERHEAD MARSHAL PATTERN	27.3%
ISS	CQPT 030	1. NO BINGO PROFILE	45.8%
		2. NO OVERHEAD MARSHAL PATTERN	29.2%
		3. NO CV 3 APPROACH	25.0%

briefings just before their scheduled training in order to fully utilize the time they had available for simulator training. They were reluctant, therefore, to spend simulator training time to use the ISS for briefing. In addition, a brief demonstration of the capabilty of the ISS, and on-the-job training on how to use it, were given by Logicon personnel for the first one or two FAM and CQ events, except for those cases during FAM training where the instructor already had been trained on the ISS. This training was given at the beginning of the training session and had the effect of reducing the amount of time available to conduct simulator training.

The unavailability of a remote ISS instructor's console and the conduct of on-the-job training prevented an accurate assessment of the extent to which the automated briefing function might have been used if a remote instructor's console had been available or of the utility of that feature. However, briefing times were collected for both IOS and ISS training. For CQ training there were no instructor briefings. The ISS was used for briefing ISS-controlled events, however this time usually consisted of demonstration and training and there was no way of assessing how much the student would have used the ISS for briefing purposes under normal circumstances. Briefing times were slightly longer for FAM training when the ISS was used, however this longer briefing time again was due primarily to ISS demonstration and training.

AUTOMATED DEBRIEFING. The ISS provided a record/playback feature and an automated performance measurement and grading capability that could be used by a student to debrief himself or as an aid to the instructor during debriefing. However, the unavailability of a remote instructor's console made it difficult for students or instructors to use these features. Normally, by the time simulator training had been completed there was little or no time remaining before the next scheduled training session. In addition, the debriefing capability of the ISS usually was demonstrated by Logicon personnel during this time.

Debriefing times were collected for all FAM and CQ events. Debriefing times averaged 12.0 minutes for FAM training conducted with the IOS and 17.5 minutes when training was conducted using the ISS. However the ISS itself was used, on the average, only 1.5 minutes per debriefing. For CQ training there were no debriefings for IOS-trained students because CQ events were self-instructed. Debriefing was available for ISS-trained students who used the ISS an average of 5.2 minutes for this purpose, however, this measure of ISS utilization includes the time taken to demonstrate its debriefing capability. Typically, there was more time available at the end of CQ training events than there was for FAM events. In addition, CQ students appeared to be interested in reviewing their performance and in obtaining some feedback concerning that performance, especially for carrier approaches and landings.

SPECIAL INSTRUCTION FEATURES. The ISS includes special instructional features in addition to those already discussed. Some of these are: computer-generated speech, automated checklists and procedures monitoring, reposition

capability, special graphics display, plus several special control features that can be effected from the ISS console (e.g. changes in environmental conditions, instrument failures, GCA wave-off and freeze).

An attempt was made to assess how often these special features were used, when utilization was an instructor's option, and to provide an estimate of the effectiveness or utility of these features from an istructional standpoint.

Table 7 shows the number of times per training session that instructional features were used or selected by the instructor. The data of Table 7 are for FAM training only; CQ events were not conducted by instructors.

The instructional features listed in Table 7, plus several features that were part of the ISS but not instructor options, are discussed briefly below.

Automated Checklist. When this feature was selected, the checklist, as depicted in the NATOPS manual, was shown on the lower display of the ISS console. The pilot's timed actions was indicated for those items that are measurable by the ISS. For those items not measurable, the instructor inserted his evaluation of student performance via "satisfactory and "unsatisfactory" touch panels also shown on the display. For FAM Class 8210 the checklist format was changed. In addition to being displayed on the ISS console the checklist was also given by the ISS automated voice-generation system. However, there was no option to have the display only.

The automated checklist is convenient because it eliminates the necessity of having a copy of the appropriate checklist available. It also is useful for monitoring pilot actions that are measurable during checklist procedures. Pilot performance of checklist procedures also is automatically recorded and can be used for subsequent debriefing purposes.

Automated checklists were used with some regularity, however the automated voice generated checklist was not well received. Students complained that the automated voice sequenced through the checklist too quickly, and that sometimes it was hard to understand. Moreover radar intercept officers (RIO), who are normally present during pilot training, preferred to have the option of making checklist calls themselves.

Computer-Generated Voice Transmissions. Voice transmissions which previously were given by the instructor to simulate the various controlling agencies were automatically transmitted to the cockpit via the ISS voice generation unit. The simulated agencies included the tower for take-off clearances, departure instructions, approach control for radar contact/approach clearances and radar vector instructions, and final conroller for CCA/GCA instructions and bolter/missed-approach instructions.

This feature was used frequently and was well received by both students and instructors. It relieved the instructor from the task of making tower

TABLE 7. AVERAGE NUMBER OF TIMES ISS SPECIAL FEATURES USED PER TRAINING SESSION

TYPE OF SPECIAL FEATURE	NUMBER OF TIMES USED PER SESSION
AUTOMATED TAKE-OFF CHECKLIST (DISPLAY)	0.83
AUTOMATED ASCENT CHECKLIST (DISPLAY)	0.33
AUTOMATED DESCENT CHECKLIST (DISPLAY)	1.00
AUTOMATED LANDING CHECKLIST (DISPLAY)	0.67
AUTOMATED TAKE-OFF CHECKLIST (VOICE)	0.00
AUTOMATED ASCENT CHECKLIST (VOICE)	0.13
AUTOMATED DESCENT CHECKLIST (VOICE)	0.13
AUTOMATED LANDING CHECKLIST (VOICE)	0.00
COMPUTER-GENERATED VOICE COMMUNICATIONS*	0.50
TRAINER REPOSITON	1.05
ENVIRONMENT OPTIONS	0.32
INSTRUMENT FAILURE	0.32
AUTOMATED GCA WAVE-OFF	0.09
TRAINER FREEZE	0.18

*This refers only to the number of times the automated voice communications was selected to give clearances. Computer-generated voice communications were always given for final approaches.

and approach communications; it also improved the standardization of those communications. The automated voice was especially useful for CQ training because there was no instructor available to simulate the normal voice communications for those events. Instructors also liked the fact that automated voice communications continued during simulated emergency conditions. This forced the pilot and RIO to contend with outside communications while coordinating their own activities and communication, which is similar to the situation they will likely encounter in actual flight exercises.

The only notable complaint about the computer-generated voice was that it occasionally was hard to understand.

Trainer Repositioning. This feature allowed the instructor to reposition the trainer to selected preprogrammed locations. The instructor had the option of selecting radar vectors to these locations.

This feature was used frequently and it effectively allowed the instructor to alter the structure of training, or to eliminate enroute flight segments. The ISS repositioning feature was less flexible than the aircraft slewing feature provided by the IOS. A limited set of repositioning coordinates were available on the ISS and these fixed coordinates included a predetermined altitude setting. On the other hand, the slewing feature of the IOS allowed the aircraft to be repositioned to any desired set of coordinates or altitude settings, although this feature is more difficult and time consuming to use.

Environmental Options. This feature provides the instructor with the option of changing environmental conditions (e.g. wind speed, wind direction, and air turbulence) and hence allowed him to increase the difficulty of flying the aircraft. The feature was occasionally selected by instructors, however, the instructional intent of selecting environmental options usually was unclear.

Instrument Failure. This feature allowed the instructor to fail the aircraft automatic throttle, ILS, or compass from the ISS console. It afforded the instructor some flexibility in altering the difficulty of flying the aircraft, especially during landing approaches.

Automated GCA Wave-off. This feature, when selected, automatically gave a wave-off call and missed approach procedures whenever aircraft approach exceeded established glide slope and azimuth parameters or whenever the instructor selected a wave-off call that required the student to practice missed-approach procedures. This feature functioned effectively, although it was not used very often.

Graphics Display. This feature provided graphic information on the upper ISS console display concerning (a) aircraft position relative to geographic positions in the form of operating areas, airways, standard instrument approaches and departures and (b) final approaches wih respect to glide slope and azimuth. This latter display showed a historical trail of

aircraft flight path with respect to desired glide slope and heading. These graphics displays occurred automatically and were not selected by the instructor or operator.

The graphics display appeared to be a useful feature especially for diagnosing or detecting landing approach or bolter pattern error. The historical trail of aircraft flight path allowed the instructor to see the overall pattern of the approach and to easily identify consistent errors revealed by the similarity of these patterns.

The graphics display is included in the ISS playback feature and potentially could be a valuable debriefing aid, especially for situations where an instructor is not available.

GENERAL MEASURE OF ISS/IOS PERFORMANCE AND OPERATION

Two measures were collected to assess the overall operation and performance of the ISS and the IOS. First, data were collected on the ease of operating the respective instructor/operator consoles, as measured by the number of errors made by instructors/operators during a normal training session. Second, data were collected on the frequency of equipment malfunctions which interrupted or interfered with training.

INSTRUCTOR/OPERATOR ERRORS. Anytime humans are required to operate or interact with sophisticated hardware, errors are likely to occur that are attributable to the human operator. The number and type of instructor/operator errors were recorded for training conducted with the ISS and with the IOS. Errors were defined as omitted actions, incorrect actions, actions performed out of sequence, or actions performed at the wrong time which were related to the operation of the instructor's console and which had a noticeable effect on training.

During FAM training an average of 1.85 instructor/operator errors were recorded per training event when training was given from the IOS. However, only 0.50 errors per training event were recorded when training was given from the ISS. Similarly, 1.5 errors per training event were recorded for CQ training when the IOS was used, but essentially no errors were recorded when the ISS was used. The lack of errors for CQ training was due to the fact that the ISS did not require an instructor or operator for these events.

Table 8 shows the most frequently committed errors and the relative frequency with which they occurred. For FAM training the most frequently committed error involved inserting the wrong malfunction, regardless of whether the training was conducted with the IOS or with the ISS. However, other operator errors that occurred when the IOS was used were essentially eliminated when the ISS was used. A similar finding was obtained for CQ training; errors attributed to the IOS operator did not occur when the ISS was used.

EQUIPMENT MALFUNCTIONS. Equipment malfunctions that interrupt or interfere with the smooth conduct of training can have deleterious effects.

TABLE 8. TYPE/SOURCE AND RELATIVE FREQUENCY OF INSTRUCTOR/OPERATOR ERRORS

FAM TRAINING

MODE OF TRAINING	TYPE/SOURCE OF ERROR	PERCENTAGE OF TOTAL ERRORS
IOS	1. INSERTED WRONG MALFUNCTION	33.3%
	2. DISCONNECTED POWER/AIR TO AIRCRAFT TOO EARLY	12.5%
	3 FAILURE TO INITIATE RUN COMMAND	8.3%
	4 FAILURE TO REMOVE WHEEL CHOCKS	8.3%
ISS	1. INSERTED WRONG MALFUNCTION	54.5%

CQ TRAINING

MODE OF TRAINING	TYPE/SOURCE OF ERROR	PERCENTAGE OF TOTAL ERRORS
IOS	1. FAILURE TO INITIATE RUN COMMAND	14.2%
	2 NO TRAINING DEVICE OPERATOR (TD) AVAILABLE WHEN NEEDED	11.9%
	3. INITIALIZATION TO WRONG COORDINATES	11.9%
	4. PROGRAMMED WRONG PARAMETER	11.9%
ISS	N/A	

Overall training effectiveness can be decreased by breaking the continuity of training or by making necessary the exclusion of some aspect of training. In addition, equipment malfunctions that occur during a training session can be frustrating for both the student and the instructor. Such frustration can, in turn, negatively affect user attitudes and influence subsequent utilization of the trainer.

The number of equipment (hardware and software) malfunctions that interrupted or interfered with training were recorded for IOS- and ISS-trained students. Equipment malfunctions that occurred during ISS training were categorized according to whether they required the ISS to be reinitialized or whether it was necessary to terminate ISS training and complete the training session with the IOS.

Overall, out of 50 ISS training sessions, nine had to be finished with the IOS because of malfunctions; seven during FAM training and two during CQ training. An additional 10 ISS training sessions were completed with the IOS because the ISS was not flexible enough to accommodate changes in training requested or desired by the instructor.

On eight occasions it was necessary to reinitialize the ISS due to equipment malfunctions. This normally interrupted training for one or two minutes, although a modification made to the ISS near the end of data collection activities allowed reinitialization to occur without interrupting training. The ISS was reinitialized an additional seven times; three times because the instructor changed his mind about what events to train, and four times because the ISS was not flexible enough to accommodate changes in training requested by the instructor.

Out of 83 training sessions conducted with the IOS, including FAPT 050 and CQPT 040, equipment malfunctions interrupted training approximately 10 times. There were no recorded instances where training, once started with the IOS, had to be terminated. Training interruptions on the IOS usually were due to a requirement to "boot strap" the computer.

The relatively high "failure" rate recorded for the ISS is somewhat misleading. In nearly every instance the requirement to terminate ISS training was due to what appeared to be a simple software error that often was solved by the next scheduled day of training. Development and modification of the ISS software continued throughout data collection activities. Therefore, the frequency of ISS errors recorded may perhaps be attributed to the fact that the ISS was an experimental prototype without sufficient time available for software debugging, rather than a table system with inherent failure problems.

SECTION V

PERFORMANCE MEASUREMENT VIEW

Performance measurement for a training system can be viewed from two perspectives as a major element in a data processing system, and as a source of information to support training activities. The data processing view is one of concern for data format, accuracy, completeness and efficiency. The information generator view is one of concern for the adequacy of the information to provide complete and understandable information for training feedback and decision requirements. Each of these views will be addressed in this section.

DATA PROCESSING

The procedure for evaluating the F-14 ISS performance measurement, from a data processing point of view, was to collect an adequate sample of data and perform trial processing. More specifically, the data analysis objectives were to (a) improve discrimination between different levels of performance, (b) improve machine-derived grades to increase correlation with those which would be determined by the instructors, (c) determine how the ISS was used including use of specific design features, and (d) evaluate the measurement implementation in terms of adequacy to achieve multiple uses of the recorded data. Unfortunately, as commented elsewhere in this report, insufficient data were collected to fully accomplish these objectives, however, the following paragraphs will address these topics to the extent possible.

METHOD. Computer magnetic tapes (Standard IBM 9-Track Format) and associated listings were obtained from Logicon, Incorporated as data were collected. There were two types of data: Audit Trail data, indicating the use of system features, and, Session data, indicating measures of student performance. The magnetic tapes were read on a DEC VAX at the Naval Training Equipment Center, Orlando, Florida, and after development of appropriate procedures these proved to be readable. Data were also transferred to 8-inch floppy disks from the DEC VAX, and then subsequently to 8-inch floppy disks in CP/M format using software acquired for this purpose. It was intended that preliminary analyses would be conducted on a Z-80 microcomputer to provide a quick examination of the data; however, as it developed, all analyses were done on the microcomputer. The microcomputer proved to be surprisingly capable, limited only by the amount of data which could be contained on the floppy disks. The microcomputer analysis included cross-checking between measures to detect outlying data points (manual checks were also conducted), regression analyses and discriminant analyses.

MEASURE DISCRIMINATION. The measurement computed in the ISS must be capable of discriminating between the performance of inexpert students, adequately performing students, expert performers, and those with performance problems of various kinds. A multivariate discriminant analysis, comparing the performance of groups of subjects for each important performance class, will permit identification of those ISS measures (if any) which can provide the desired discriminations.

A ridge-adjusted discriminant analyses was programmed in the FORTRAN computer language. A non-parametric version is also available for small samples. These analysis tools were applied to samples of the available data as a test of data quality, however, sufficient quantities of data did not become available to permit fully executing these analyses. Nevertheless, based on the data examined, data quality from the ISS should suffice for these purposes, and the complete analysis can be conducted when additional data collection is accomplished.

CORRELATION WITH INSTRUCTOR GRADES. A multivariate regression analysis was developed with the objective of identifying key measures and appropriate weightings which could then be used to compute scores and grades equivalent to those produced by the instructors. A standard regression analysis and a ridge-adjusted regression analysis were programmed in FORTRAN. These programs were tested with constructed standard data and with data collected on the F-14 ISS. Since the only data collected in any quantity were landings of various types, these were collected together to form a composite test data base (a total of 43 landings).

A measurement structure was used in the ISS wherein a parameter, such as Glideslope or Centerline deviation, was divided into three regions termed ON, SLIGHTLY OFF, and WELL OFF. A count of the number of samples of data in each category was made and then a percentage of the total number of samples was calculated. The regression analysis found the ON and WELL OFF measures to be negatively correlated (.84 - .95) as could be expected (e.g. pilots who were not on course were therefore off course), one of the two measures had to be deleted to conduct a successful regression analysis. This undesirable redundancy should be considered in any redesign of ISS measurement.

Unfortunately, the regression analysis could not achieve the intended goal since the small amount of data collected consisted mainly of student-only training, without, of course, any instructor grade recorded. Nevertheless, the analysis stands in readiness, and can be executed when suitable types and quantities of data are available.

USE OF DESIGN FEATURES. A FORTRAN program was prepared to tabulate the use of identified system features for each month of Audit Trail data. As shown in Figure 4, a count of system features for each type of user is tabulated, and the total number of hours of use for each type of user is calculated. These data should permit identification of those features which are heavily and lightly used. Given adequate quantities of data, these should provide valuable information for system analysis and redesign.

ADEQUACY OF DATA GENERATED. As noted above, the data collected were subjected to a variety of computer analyses. These analyses contained checks on the range of values and relationships between parameters when possible. All data were listed and manually reviewed. As a result of these inspections numerous errors were found; however, in all cases these were either the result of aborted demonstration sessions, equipment malfunctions, or software bugs. All errors were judged to be correctable and data error

USE OF ISS FEATURES SEP

FEATURE	INSTR	STUDENT	TEST	OTHER
LOGON	27	32	143	0
IDENT STUDENT	10	0	13	0
ENTER EX. DEFIN.	0	24	33	0
REINT EX. DEFIN.	0	3	6	0
COMPL EX. DEFIN.	0	24	29	0
BRIEF MISSION	13	21	89	0
ACTIV. MALF.	20	10	14	0
REMOVE MALF.	16	5	2	0
SEL. ENVIR. OPT.	20	0	9	0
REPOSITION A/C	9	2	5	0
EXAMINE CHKLST	25	6	10	0
REMOVE CHKLST	1	0	1	0
SEL. MAN. MODE	4	17	30	0
FREEZE SYS.	0	0	7	0
REQU. HARDCOPY	1	6	74	0
REQU. AUTOVOICE	0	0	0	0
DEBRIEF MISSION	11	33	42	0
EXAMINE CRITERIA	0	4	13	0
PLAYBACK MODULE	4	38	3	0
CHANGE GRADE	0	0	5	0
LOGOFF	22	37	182	0
REVIEW SUMMARY	1	2	7	0
REVIEW EXPANDED	1	4	16	0
VIEW DISPLAY	13	9	18	0
HRS USE	2.1	12.9	12.0	.0

Figure 4. Example Audit Trail Data Summary

should eventually be at an acceptably low rate. It should be noted that the data collected did support the audit trail and regression analyses--proof that the data quality can be made to be acceptable. Consideration of the adequacy of the data with regard to information content is given in the following section.

INFORMATION GENERATION

The other aspect of performance measurement to be considered here is that of generating the information necessary for the conduct of training and associated activities. The information requirements will be discussed first to identify the role measurement is to play for the ISS, and following that, specific performance measurement design issues will be discussed.

It should be noted that the ISS design occurred circa 1978 while the discussion presented in this report draws upon new data, new concepts and experience which were not available then. It should be remembered that the ISS was designed within tight real-life contraints, and that the finished product did, in general, function satisfactorily. Furthermore, while some improvements may appear to be quite desirable, detailed analysis will be required to determine engineering and economic feasibility.

INFORMATION REQUIREMENTS. The ultimate purpose of performance measurement is to provide information in support of some activity or decision; it is certainly not an end unto itself. It is desirable, therefore, to consider the end uses before attempting to assess the specific details of performance measurement for instructional support.

Users of Performance Measurement. The end users of an instructional support system include, of course, the instructors and students, but also developers of new or revised training material, system test and maintenance personnel, training system managers, system developers, and the system itself for various automatic functions. Each of these has individual requirements for information from the training system, and the performance measurement subsystem must satisfy these needs. An extensive analysis of the needs of each is not appropriate here, but it should be clear that a system that only attends to the needs of the student and instructor will fall short of the possible ISS potential.

Modes of Operation. The principal modes of operation for the ISS are CANNED, ISEL and SST; however, the ISS must permit the creation and modification of task modules, the creation and test of CANNED and ISEL programs, the training of new instructors in the use of the ISS and applications for training, and the test of the system to ensure that it is functioning properly. While the latter are not the primary modes of the ISS, performance measurement must come into play for each, and, in the case of system tests, the performance measurement itself should be included in testing for proper operation.

Functions. An instructor will probably begin an ISS session reviewing student progress by perusing reports generated by the performance measurement

system. Then the ISS must support briefing and debriefing, and at times provide these functions automatically for the student to receive appropriate feedback when an instructor is not present. The ISS must provide simulator setup and initialization, which through the task module definitions define the performance measurement to be applied during each segment of training. In addition to performance measurement, per se, the ISS must provide for the automatic generation of grades and the automatic generation of a prescription for future training.

Training System. The ISS is part of a larger training system and should provide information for training management, instructional design and research. The performance measurement system will therefore need to provide backup information to grades, detailed archival data for subsequent analysis, adaptive logic, and other information for the management and continued development of the ISS.

A Context For Assessment. The above presentation of users, modes, functions and training system environment is intended to provide a context for performance measurement assessment within the ISS. However, it should be noted that the specific implementation of the ISS, which is the focus of this report, may not have addressed the entire context due to time and budget constraints. This reality will be put aside and for present purposes, the full potential of the ISS will be taken as a context for assessment.

PERFORMANCE MEASUREMENT DESIGN ISSUES. Major measurement system functions, as depicted in Figure 5, are: (a) sampling, (b) segmentation, (c) scoring, (d) performance alerts, (e) grading and (f) condensed time history recording. These functions must answer to the requirements for information as outlined previously. The structure presented in Figure 5 is intended as an aid for comparison against generic measurement requirements. (Note that the ISS measurement is accomplished within concurrent task modules; the actual implementation, while including the functions shown in Figure 5, is not implemented as the blocks shown in Figure 5.)

Parameter Sampling. The measurement process depends on sufficiently fine-grained sampling of system state variables so that the essential characteristics can be reproduced and reflected in computed measures. The ISS design provides for three types of sampling categories: (a) continuous, wherein a mission segment has predefined start and stop conditions and the associated parameters are sampled 1 to 20 times per second, (b) monitor, wherein a parameter is sampled during the time that it is outside a predefined limit, and (c) snap shot, wherein a single parameter is sampled once.

This structure provides an excellent basis for subsequent performance measurement calculations and should be sufficient for future requirements across the full spectrum of users, modes, functions and management needs. Past experience indicates that the sampling rate provided is more than sufficient. Most flight parameters need only be sampled two times per second, while only values such as pilot stick inputs, formation deviations and air-to-air mission parameters need to be measured up to 10 times per second, and final segments of air-ground weapons delivery require sampling at 20

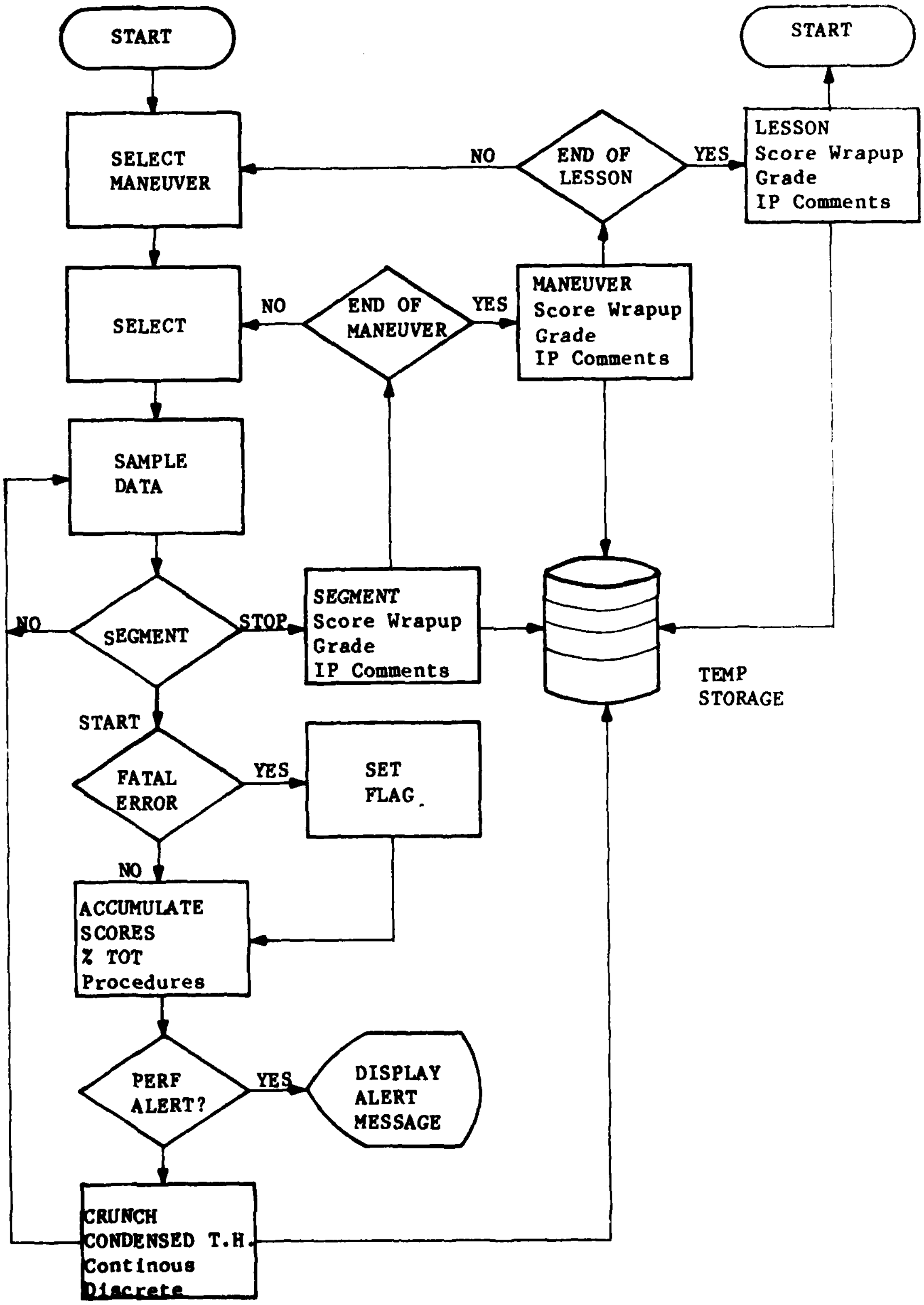

Figure 5. Measurement System Function Flow Diagram.

times per second. In fact, for mass data storage for research purposes, consideration should be given to compressing or packing some of the information (such as recording only snapshots when a discrete change occurs).

Segmentation. The start and stop of segments of maneuvers for measurement, and the scoring of performance within these segments, are included as part of the task module definitions. Start and stop of measurement segments are defined in terms of discrete events such as "weight off wheels" and "weight on wheels". While this method is often adequate, it falls short in terms of permitting unequivocal definition for start and stop of basic segments such as simple turns. Logic based on two parameters is generally desirable. Further, a better algorithm results when a window (5-15 seconds) of parameter storage is maintained, so that the logic permits examining trends. This will permit the initiation of a turn to be distinguished from a course correction maneuver. Further simplification can result when the next segment is always known; then it may be possible to eliminate start logic by using the method that the next segment is known and that it can start when the previous segment end conditions are met. Apparently the ISS start/stop logic did work for the implemented task modules during the tests performed for this study. On the other hand, experience has indicated that multi-parameter logic and the windowing technique are sometimes required. Therefore, it is recommended that consideration be given to start/stop logic refinement.

The ISS, as implemented, permits the definition of measurement as part of each task module; however, measurement may require multiple segments within a single task module. For example, each module for continuous flight control should be divided into at least three parts: (a) capture (e.g., transition or intercept) of a steady state course, (b) course tracking (e.g. regulator behavior), and (c) departure from course, or recovery (another transition). Such subdivision of global task modules will be necessary to produce performance measurement that reflects fine-grain pilot performance.

Scoring. ISS scoring for continuous performance frequently invokes the concept of measurement of deviation from a fixed value, or exceeding a fixed value. Figure 6 depicts a phase-plane approach derived from control system theory, which treats limits in terms of two parameters (defining a plane) rather than attempting to treat performance in terms of one parameter at a time. Use of the phase plane involves a position parameter and the corresponding rate parameter (e.g., altitude and rate-of-climb). In these terms, the plane can be used to define a central area of acceptable performance, with the remainder divided into zones in which the state is either converging to the proper level or diverging. Only the diverging zone represents what is ordinarily considered deviant performance, and thus should be the basis for scoring. The phase-plane approach is recommended for consideration in future ISS development.

Since students and instructors are primary users, it is important that the measurement be displayed to them in terms that are easily interpreted by them. The implemented ISS, however, presents such scores as the

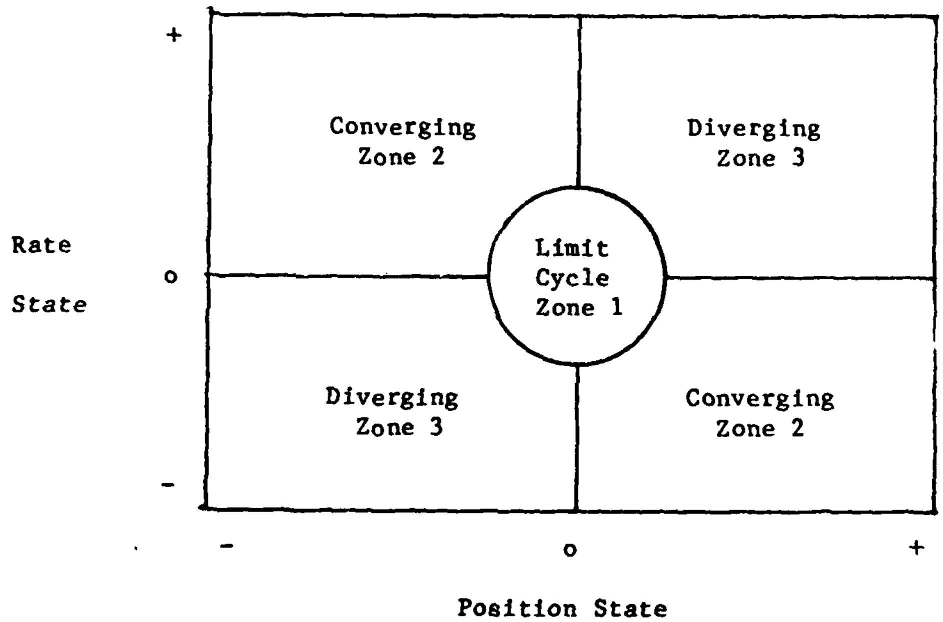

Figure 6. Example Phase Plane Representation.

Root-Mean-Squared (RMS) Error which are not part of the normal flight terminology. It is recommended that such measures, if used, be used as the basis for generating messages which are presented in ordinary pilot language as represented by the usage in current flight training manuals.

It is believed that the presentation of scores in terms of tolerance bands about desired performance is a scoring method that is easily understood by pilots. The main disadvantage, however, is that these measures give no information about performance above and below the tolerance level. An ill-chosen tolerance band will not discriminate between different students, and frequently the actual performance accuracy is lost. An alternative that somewhat offsets this criticism is to use multiple tolerance bands, and, it is suggested here that three levels of performance tolerances be used for assessment purposes. This approach has implications to scoring which will be discussed below. The first tolerance band will represent superior performance, the second will represent good performance, and the third will represent the outer limits of commonly accepted operational criteria. Furthermore, momentary excursions shall be permitted by other criteria which specify the amount of time a system state variable can be in a category before the measurement system will recognize the fact. For measurement development, however, the RMS measure is an effective global measure of performance.

<u>Procedures Monitoring</u>. Measurement of pilot performance during normal and emergency procedures requires sensing of a large number of pilot devices. In addition to the necessary switches for the given procedure, the nearby and functionally related switches must also be sensed in order to measure erroneous inputs. There are, of course, some pilot actions which cannot be readily sensed (e.g. communications) and Instructor monitoring of these is necessary to augment the automated monitoring. Each activation must be checked against the allowable sequence. For example, it may not matter whether a given procedural event occurs before or after some other events, but must occur before or after some specific events. Furthermore, there may be certain contingencies for some events; for example, application of nose-wheel steering on takeoff may be optional prior to 15 knots, mandatory from 15 to 85 knots, and not to be used above 100 knots.

In addition to switch position and sequencing, the performance measurement included recognition reaction time and total time to complete a procedure. Switch positioning could be weighted as mandatory, critical or optional. Performance measurement therefore included percent of mandatory actions taken and percent of optional actions. A check list or malfunction procedure could be presented to the instructor and each step in the procedure noted as it is accomplished. The time for each step is displayed and errors of omission or comission result in the display of diagnostic messages.

Procedures monitoring of the sophistication and complexity developed in the implemented ISS is a pioneering effort with little precedent. For example, measurement of errors of comission is an inherent problem since all possible switch actions often cannot be scanned within available computer

time; the alternative is the investment of large amounts of analysis to identify reasonable numbers of nearby and functionally related switches. However, procedures monitoring is one of the strongest features of the ISS performance measurement. It is unfortunate that detailed empirical testing of this specific feature was not accomplished, but the procedures monitoring feature appears to be fundamentally sound. Procedures monitoring is a performance measurement feature which can contribute significantly to instructor unburdening and is worthy of additional research and development to refine and verify the design.

Performance Alerts And Messages. The diagnostic messages presented to the instructor during student training are practical and in operational language. These are good examples of the position advocated above. Performance messages should provide diagnostic information as these seem to do, and should enable the generation of remedial strategies. The checklist displays to the pilot permit the instructor to follow the sequencing of actions and note errors of omission and commission. These appear to be quite satisfactory. The inclusion of response times and time of action may or may not be useful to the instructor, but may be of value for research and development purposes.

Grading. Grading, in the implemented ISS, is in terms of the range in which a computed measure falls. As the grading structure is displayed to the instructor, and should be understandable, this scheme has some merit. However, the grade is based on gross measures which may not be very sensitive to brief, but serious, performance deviations. It is recommended that a grading scheme be considered based on the three-tolerance band scheme described above. A five-point grading scale could be used as shown in Table 9, and the maneuver grade would be as shown in Table 10. Grading and certain performance monitoring functions are simplified if serious errors are always monitored (as the implemented ISS is capable of doing). Fatal errors should be displayed to the instructor as exemplified in Table 11; these errors should cause an automatic failure of a segment and the maneuver.

Condensed Time History Recording. The implemented version of the ISS does not permit additional detailed performance analysis during debriefing, nor does it permit the computation of detailed additional measures at a later date for research purposes. The capability should exist so that detailed supplemental performance measures can be calculated during debriefing when the instructor is attempting to provide diagnosis and feedback to the student. Time history recordings are necessary to permit these analyses. To permit detailed analysis during debriefing the time history data must be retained in the ISS; however, it can be subsequently spooled out to tape, or some other convenient form, for long-term storage. The stored data must include both continuous and discrete state variables, but only within designated measurement segments, and possibly in packed format (e.g., record and time-stamp data only when discrete changes occur).

TABLE 9. EXAMPLE SEGMENT GRADE CRITERIA

Performance Level	Conditions	Segment Grade
EXCEPTIONAL Unusually accurate performance	No Measures Exceed Tol 1	5
ABOVE AVERAGE All measures well within acceptable tolerance	All Measures within Tol 1 or 2 No Measures Exceed Tol 2	4
AVERAGE All measures within acceptable tolerance	All Measures within Tol 1 or 2 and 3 No Measures Exceed Tol 3	3
BELOW AVERAGE All measures within acceptable tolerance, but very close to the limits	No Measures within Tol 1 and 2 No Measures exceed Tol 3	2
UNSATISFACTORY At least one measure out of acceptable tolerance	Any Measure Exceeds Tol 3	1
SEGMENT NOT COMPLETED OR FATAL ERROR	___	0

TABLE 10. EXAMPLE MANEUVER GRADE CRITERIA

Performance Level	Segment Grade	Maneuver Grade
EXCEPTIONAL Unusually accurate Performance	AVG* $\geq$ 4.7	5
ABOVE AVERAGE All segments well within acceptable tolerance	4.7 > AVG $\geq$ 3.7	4
AVERAGE All segments within acceptable tolerance	3.7 > AVG $\geq$ 2.7	3
BELOW AVERAGE All segments within acceptable tolerance, but very close to limits	2.7 > AVG > 2.0	2
UNSATISFACTORY	Any Segment = 1	1
MANEUVER NOT COMPLETED OR FATAL ERROR	Any Segment = 0	0

*AVG = Sum of Segment Scores divided by Number of Segments Flown.

TABLE 11. EXAMPLE FATAL ERRORS

	Fatal Error	Comment
1	Excessive high or low Airspeed	± 30 knots from desired
2	Excessive Bank Angle	± 30 degrees from desired
3	Excessive high or low Altitude	± 250 feet from desired
4	Excessive Rate of Descent (One minute to live rule)	VV greater than altitude above the ground
5.	Excessive Time in a Segment	tbd, each segment
6.	Violation of Airspace Limits	tbd, each segment
7.	Turning in wrong direction	tbd, each segment
8.	Climb or Descent in wrong direction	tbd, each segment
9.	Descent below MDA or DH	- 50 feet from MDA or DH
10.	Improper radio frequency when critical	tbd, each segment
11.	TACAN T/R switch not set when DME is critical	tbd, each segment
12.	Improper Altimeter Setting	± 0.02 from desired to include changeover at 18,000 feet
13.	Landing Gear up	

SUMMARY

The implemented ISS was developed under stringent time and budget, constraints, which limited ISS performance measurement development. However, training and research applications will benefit if additional resources can be provided for performance measurement development to be carried beyond the present stage. One must consider the full matrix of (a) users, modes, functions, and training management interface by (b) measurement characteristics of sampling, segmentation, scoring, messages, grades and time history recording. It is considered most important that performance measurement development be advanced in the following areas: (a) full support for all users, (b) segmentation schemes appropriate to fine-grained performance measures, (c) scoring to reflect detailed performance in pilot language using a multi-level tolerance band scheme, and (d) time-history recording to permit detailed analyses for debriefing and research. Nevertheless, the existing task module and performance measurement scheme does have a sound basis, and the ISS as currently developed can provide the performance measurement needed to support global instructional and research evaluations.

SECTION VI

CONCLUSIONS

This report has presented a review of the ISS concept from three different points of view; however, the foremost concern at this point is for the principal objectives of the ISS: to increase simulator utilization and thereby reduce training costs, and to improve simulator training quality. These topics will be discussed in the following along with recommendations for advancement of the ISS design concept.

UTILIZATION

TRAINING WITHOUT AN INSTRUCTOR. Clearly simulator utilization can be increased if the simulator can be used without an instructor being present at each training session. Furthermore, the needed enhancements also provide distinct advantages for the training normally conducted without an instructor present (e.g., the first three CQ training events), student-scheduled extra-time training events and use of the trainer by fleet personnel. The ISS permits accomplishment of training with little or no assistance from either an instructor or a training device operator, and therefore enables use of the simulator facilities with less constraint by the available amount of instructor labor.

Of course, the instructor serves a number of instructional functions in addition to operation of the simulator, and feedback to the student about his performance is an important function to be automated to improve instructorless training in the simulator. While the existing ISS performance measurement provides much good information, especially for procedures training, additional ISS performance measurement capability (e.g., tough instructorless trial checkrides) is required.

CONCURRENT BRIEF/DEBRIEF. Unfortunately, in its present stage of implementation, the ISS was little used for briefing and debriefing. However, the ISS concept does include briefing and debriefing which can provide needed preparation for simulator training, much out-of-simulator learning, and reinforcement of the training received. Furthermore, the ISS concept can provide for briefing and debriefing concurrent to simulator training, so that the simulator can be used by one student while another is being briefed or debriefed. With this approach, simulator utilization can be increased without sacrificing the important training advantages of briefing and debriefing. Otherwise, unfortunately, there is pressure to skim through the briefing so that simulator time is not wasted, or to hurry the debriefing because the next student is scheduled to get on the simulator.

TRAINING QUALITY

INSTRUCTOR WORKLOAD. Reduction of instructor workload should result in improved training, for if the instructor is busy manipulating the simulator it is probable that critical periods of performance will not be monitored. Use of the ISS could reduce instructor workload in several ways: automated

briefings allow a student to brief himself with little or no assistance from the instructor. Automated performance measurement and procedures monitoring capability of the ISS frees the instructor from keeping records and notes of student performance. The automated voice generation feature frees the instructor from making many support communications. Further, automated malfunction insertion frees the instructor from switch manipulation. Consequently, the instructor should be unburdened by the ISS and permitted to place greater emphasis on instructional duties.

STUDENT PERFORMANCE DATA. ISS features provide the instructor with more detailed information about student performance than is normally available. Procedural responses and performance scores for each task module are displayed. This information can be used in real time to modify training and provide timely feedback to the student, or it can be used during debriefing for instructional impact at that time and for determination of a prescription for the next training session. The availability of information for immediate feedback should result in a clear-cut improvement in training. Further, the automated record keeping of ISS would allow an instructor the opportunity to review a student's previous performance prior to a training session. This would orient training toward an individual student's needs, especially in an environment where a student is not assigned to a single instructor.

STANDARDIZATION OF TRAINING. Standardization of training can be increased through ISS features such as CANNED mode missions, standard training modules, standard briefings and automated measures of performance. Unfortunately, instructor pilots may not elect to use some of these features in the current implementation, or may not use some features due to inadequate training in use of the ISS. Also, standardization may not always be considered a virtue by the instructors, who may consider standardized training as inflexible. While not resolving this issue, the ISS concept does allow centralized control of training as well as means for flexibility through automation and manual options. Consequently, the ISS provides a tool for control by the training manager and should allow any degree of standardization to be determined through future research.

HUMAN ENGINEERING. The ISS, as currently configured, provides a compact workstation which is easily reached and viewed, providing a comfortable and functional interface for the instructor. Uncluttered integrated displays provide information in a convenient form. The touch panel control surfaces provide an environment which permits design not permitting illegal inputs (again, except for parallax problems). While some areas for improvement remain, the ISS workstation is a major step toward providing an environment to enhance instructor effectiveness.

RECOMMENDATIONS

While the current review resulted in favorable findings for the ISS concept, there are a number of issues to be remedied for the current ISS implementation and features of the concept to be emphasized. Recommendations for selected topics are presented in the following paragraphs.

BRIEF/DEBRIEF STATION. Inability to use the remote ISS station for briefing was clearly a major deficiency in the current ISS implementation. The use of a separate station for briefing and debriefing has large potential training benefit, and as pointed out above, also has large potential impact on equipment utilization if the brief/debrief station can be used simultaneously with the simulator. The brief/debrief station can be used to review progress, modify the lesson, setup parameters for the simulator, review lesson scores and grades, and generate prescriptions of next lessons. These activities could all be accomplished while another student is performing in the flight simulator. Upgrade of the design and the concept for a concurrent brief/debrief station is therefore recommended.

PERFORMANCE MEASUREMENT. Existing ISS performance measurement has some features which provide insufficient detail and which are not in terms ordinarily understood by pilots. Furthermore, the performance measurement system does not permit the storage of detailed time histories of performance for analysis during debriefing or at a later time for research purposes. Some revision to the scoring scheme and a mechanism for data storage is therefore recommended. These improvements will be required to make the ISS a suitable testbed for research purposes.

USER-SOFTWARE INTERFACE. The ISS software design is based on a structure of task modules containing detailed information for describing segments with specific learning objectives. While this appears to be an excellent design choice, the development of task module definitions proved to be an extremely labor-intensive activity which could only be performed by the design contractor. Consequently, total task module definition for all VF-124 lessons did not occur even within the course of this study. The difficulty in defining and modifying task modules can be a serious deficiency, especially in a dynamic training environment. It is therefore recommended that a better task module definition interface be developed, one which would permit instructional designers to program the ISS without assistance from the design contractor. This might take the form of a user interface language or an interactive utility program.

INSTRUCTOR TRAINING. ISS effectiveness is heavily dependent upon the ability of the instructors to use it as designed. And, except for the instructorless mode, the ISS is a tool intended to enhance the instructor's effectiveness. It is therefore exceedingly important that adequate instructor training be given, as well as that adequate help functions be implemented in the ISS.

FLEXIBILITY. While standardization is desirable, it is also important that instructors have sufficient flexibility to modify the chosen syllabus with variations to enhance training or efficiency. The existing IOS allowed more flexibility in, for example, selecting simulated malfunctions and in slewing the aircraft position than did the ISS. Less flexibility to alter training contributed to requirements for increased planning in ISS training. It is therefore recommended that ISS flexibility for instructional control be increased (within specified syllabus constraints).

HUMAN ENGINEERING. While good human engineering was exhibited in the ISS in general, specific deficiencies as noted in this report require correction.

ADDITIONAL EVALUATION. The present evaluation should be viewed as a pilot study of an evolving system. An additional evaluation of the ISS will be necessary to provide a conclusive assessment of its contribution to increased simulator utilization and improved training quality. However, an additional evaluation will be worthwhile only if a number of conditions under which it is conducted are different from the current study. Appendix C provides detailed recommendations for subsequent evaluation.

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APPENDIX A

PRE-USE INTERVIEW GUIDE

What experience have you had with computer systems?

a. Large data processing systems
b. Computer supported training
c. Home computer systems
d. Small business systems (word processors)
e. Other

What do you think of the use of computer systems in training?

Do you think computers can improve the quality of training?

Do you think modern, highly computerized instructor consoles will result in improving your skills as an instructor?

In your opinion will compu^er assists to training be difficult to use?

Do you expect any problems in setting up instructional problems on highly computerized instructor consoles?

Do you think computers can simplify your job as an instructor?

Do you think it is reasonable for computer models of controllers to "talk down the pilot" for carrier landing simulations?

How do you feel machine generated student performance scores will be accepted by:

a. instructors in general
b. students
c. you?

Do you prefer guages or digital readouts for functions such as altitude, angle of attack, etc.?

Which do you prefer: Computer touch panel or mechanical switches?

Do you expect ISS will give more complete information for instructor/student use compared to present system?

APPENDIX B

POST-USE OBSERVATION AND INTERVIEW GUIDE

Describe Training Observed

Log-On

- Time required (measure)
- Procedural sequence/organization
- Ease/difficulty

Briefing/Debriefing

- Summarize training missions involved
- Identify modes used in training (CANNED, ISEL, STT)
- Describe briefing uses of ISS
- Describe briefing strengths/weaknesses
- Describe debriefing uses of ISS
- Describe debriefing strengths/weaknesses

CANNED Mode Training

- When used (describe student and training mission)
- Training problem set-up (ease/difficulty; describe specific events)
    - Initial set-up
    - Making revisions
- Shifting to other modes
    - When and why
    - Ease/difficulty (describe specific events)

ISEL Mode Training

- When used (describe student and training mission)
- Training problem set-up
    - Initial set-up
    - Making revisions
- Task modules used (relative frequency)
- Shifting to other modes
    - Why and when
    - Ease/difficulty

STT Mode Training

- When used (describe student and training mission)
- Training problem set-up
- Task modules used (relative frequency)
- Shifting to other modes
    - When and why
    - Ease/difficulty

Performance Monitoring/Measurement (Uses and Values)

Procedure sequence and timing display
Summary scores
First level score detailing
Flight profile graphics display

APPENDIX C

RECOMMENDATIONS FOR SUBSEQUENT EVALUATION

Several recommendations for a subsequent evaluation of the ISS are provided below:

- A pre-evaluation period should be established to ensure that the ISS is ready to be evaluated and to ensure that instructors are adequately trained before the evaluation begins.

- The data collection period should be long enough to collect data for approximately 15 students for each control and experimental group contained in the study. Current estimates suggest that about 9 months would be required.

- The ISS should be developed to train 10-15 Device 2F95 events. To the extent possible all of the events for a given stage of training (e.g. FAM, CQ, etc.) should be developed for ISS training. Otherwise simulator training for each stage of training consists of a mixture of training conducted with the IOS and the ISS. This makes it difficult to assess the contribution of ISS training to student performance.

- ISS training modules should be fully developed and debugged before the evaluation begins. Moreover, no major changes should be made to these modules during the evaluation.

- Instructor training should be completed before the evaluation begins. It may be advisable to select a small group of instructors and train them to operate the ISS, rather than trying to train all of the instructors in the squadron.

- Instructor training should include some instruction on how to take advantage of the instructional capability of the ISS.

- A functional, remote (off-line) ISS instructor's console should be available.

- Sufficient time should be scheduled for instructors to complete simulator training, including a designated briefing and debriefing period. This would provide instructors with a scheduled opportunity to use the briefing/debriefing capability of the ISS.

- Measures of student performance need to be expanded or complemented with additional measures. The development of specific behavioral objectives which the ISS is expected to achieve provides one possible solution; the development of a more sensitive instructor grading scale provides another.

Although these recommendations are specific to an evaluation of the ISS, they do provide guidance for training effectiveness evaluations of other instructional support devices.

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